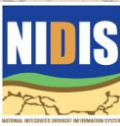


# **The NDMC and CALMIT: Drought Monitoring Activities**

**Mark Svoboda, Climatologist  
Monitoring Program Area Leader  
National Drought Mitigation Center (NDMC)  
School of Natural Resources  
University of Nebraska-Lincoln**

**and  
Brian Wardlow, Director  
Center for Advanced Land Management Information  
Technologies (CALMIT)  
School of Natural Resources  
University of Nebraska-Lincoln**

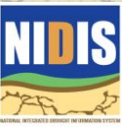
**JPL Seminar, Pasadena, CA November 7, 2012**



# National Drought Mitigation Center

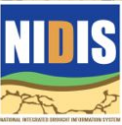


**Mission:** To lessen societal vulnerability to drought by promoting planning and the adoption of appropriate risk management techniques.



# National Drought Mitigation Center

- Established in 1995
- Founder: Dr. Don Wilhite
- Current Director: Dr. Mike Hayes
- Evolved out of the International Drought Information Center (IDIC)(late 1980's)
- Staff: 16 people, tremendous diversity
- **Bridge and translate science** to policy/decision makers, media, and the public
- **Program Areas:** Monitoring, Planning and Social Science, GIScience
- Operational tools, research, outreach, training
  - "Research to Operations to Applications to Education" **End-to-End Continuum**

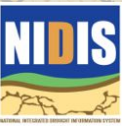




# NDMC Program Objectives

- ▶ ***Improve the science*** of drought monitoring, planning, and mitigation
- ▶ Build ***awareness*** of drought and its ***impacts*** on society and the environment, and how human actions affect our ***vulnerability*** to drought
- ▶ Focus the attention of policy makers on the importance of ***drought policy and planning*** in the wise stewardship of natural resources

***"End-to-End": Research-Applications-Operations-Outreach Continuum working w/ our users...***





**Legend:**  
 Red: Countries with meteorological services.  
 White: Countries without meteorological services.

**Notes:**  
 The map shows the distribution of meteorological services across the world. Countries are colored red, indicating the presence of such services. The map shows a high concentration of red countries in North America, Europe, and Australia, with fewer red countries in South America, Africa, and Asia.

- ***UN organizations:***  
FAO, ISDR, and CCD
- ***World Meteorological Organization (WMO)***
- ***USAID***
- **Various regional and national drought centers**
- **Numerous government agencies and universities in different countries**

### Activities 2005–2011

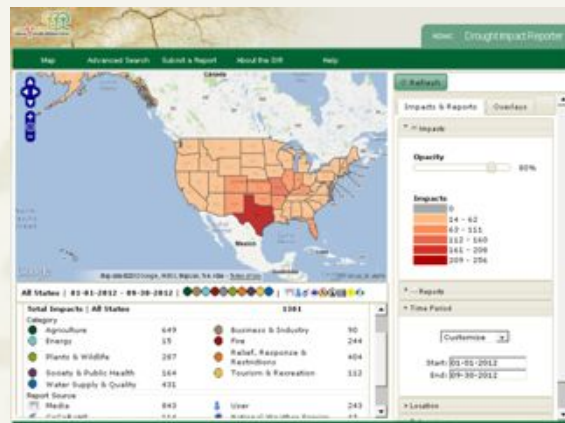
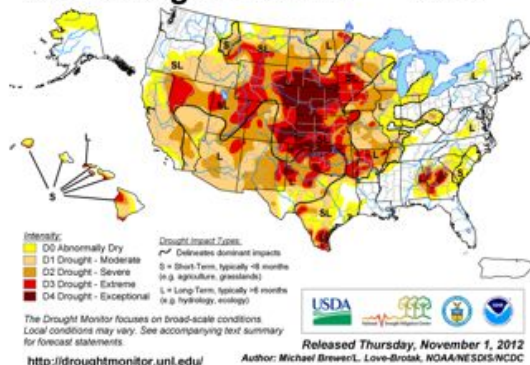
**Australia • Austria • Brazil • Cambodia • Canada • Chile • China • Czech Republic • Egypt • Ethiopia**  
**• European Union • India • Iraq • Italy • Japan • Jordan • Mali • Mexico • Morocco • Mozambique • Namibia**  
**• Netherlands • Saudi Arabia • Slovakia • Slovenia • South Korea • Spain • Switzerland • Syria •**  
**Tunisia • Turkey • United States • Vietnam • Zambia**

# NDMC's Monitoring Program Area

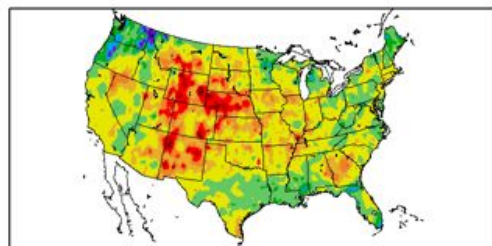
**Monitoring**

**Activities**

## U.S. Drought Monitor October 30, 2012

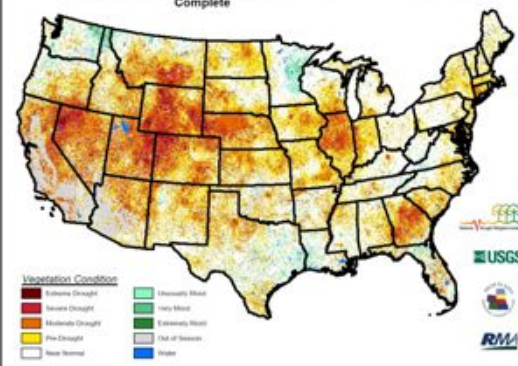


Year-to-date SPI  
 1/1/2012 - 11/1/2012



## Vegetation Drought Response Index Complete

July 23, 2012

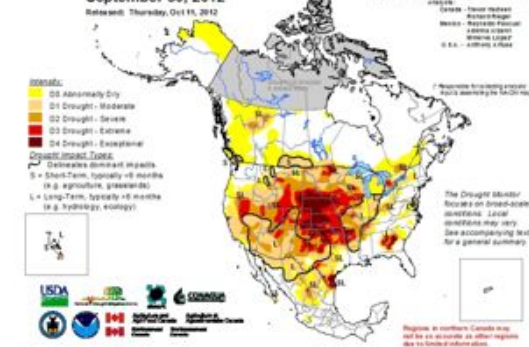


**National  
 International  
 USDM  
 NADM  
 DIR  
 Daily Gridded SPI  
 NIDIS**



## North American Drought Monitor

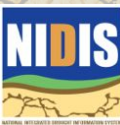
September 30, 2012





# Tools for Planning: NDMC and NIDIS

- ▶ Planning at ***all scales***
- ▶ All droughts are ***"local"***
- ▶ Planning should start local and involve the ***"locals"***
- ▶ Planning is a ***"living"*** process

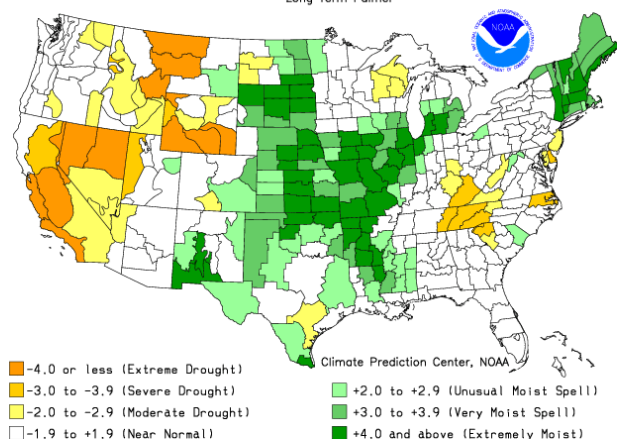




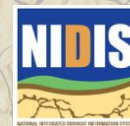
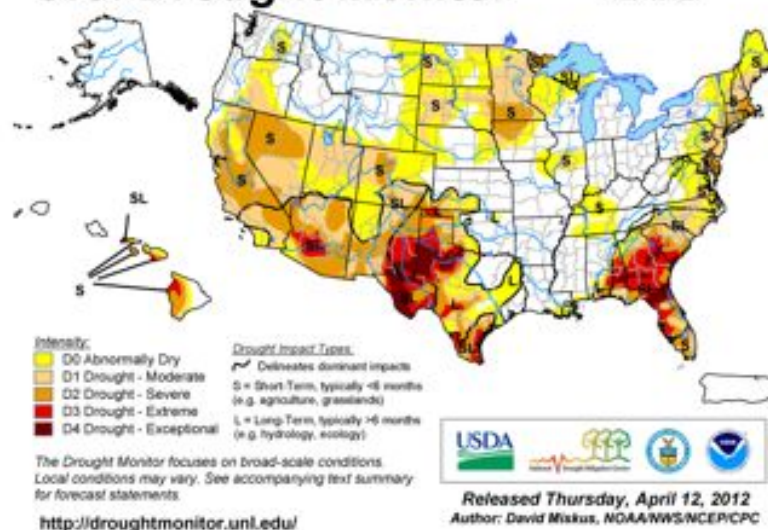
# Approaches to Drought Assessment

- Single index or indicator (parameter)
- Multiple indices or indicators
- **Composite (or "hybrid") Indicator**

Drought Severity Index by Division  
Weekly Value for Period Ending OCT 18, 2008  
Long Term Palmer



U.S. Drought Monitor April 10, 2012  
Valid 7 a.m. EDT



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Lincoln

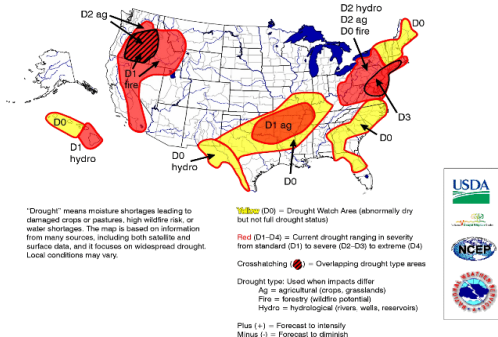


# The U.S. Drought Monitor

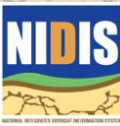
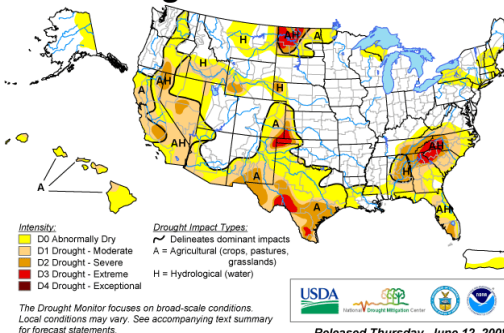
Since 1999, **NOAA (CPC, NCDC, WRCC), USDA, and the NDMC** have produced a weekly composite drought map -- the U.S. Drought Monitor -- with input from numerous federal and non-federal agencies

- **Western Region Climate Center** on board 2008
- **11** authors in all
- **Incorporate** relevant information and products from all entities (and levels of government) dealing with drought (RCC's, SC's, federal/state agencies, etc.) (**~350 experts**)

August 3, 1999  
**Experimental U.S. Drought Monitor**



**U.S. Drought Monitor** June 10, 2008  
Valid 8 a.m. EDT



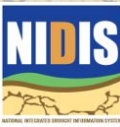
UNIVERSITY OF  
**Nebraska**  
Lincoln



# Objectives



- “Fujita-like” scale
- **NOT** a forecast!
- **NOT** a drought declaration!
- Identify **impacts** (S, L)
- Assessment of **current** conditions
- Incorporate **local expert** input
- Be as **objective** as possible

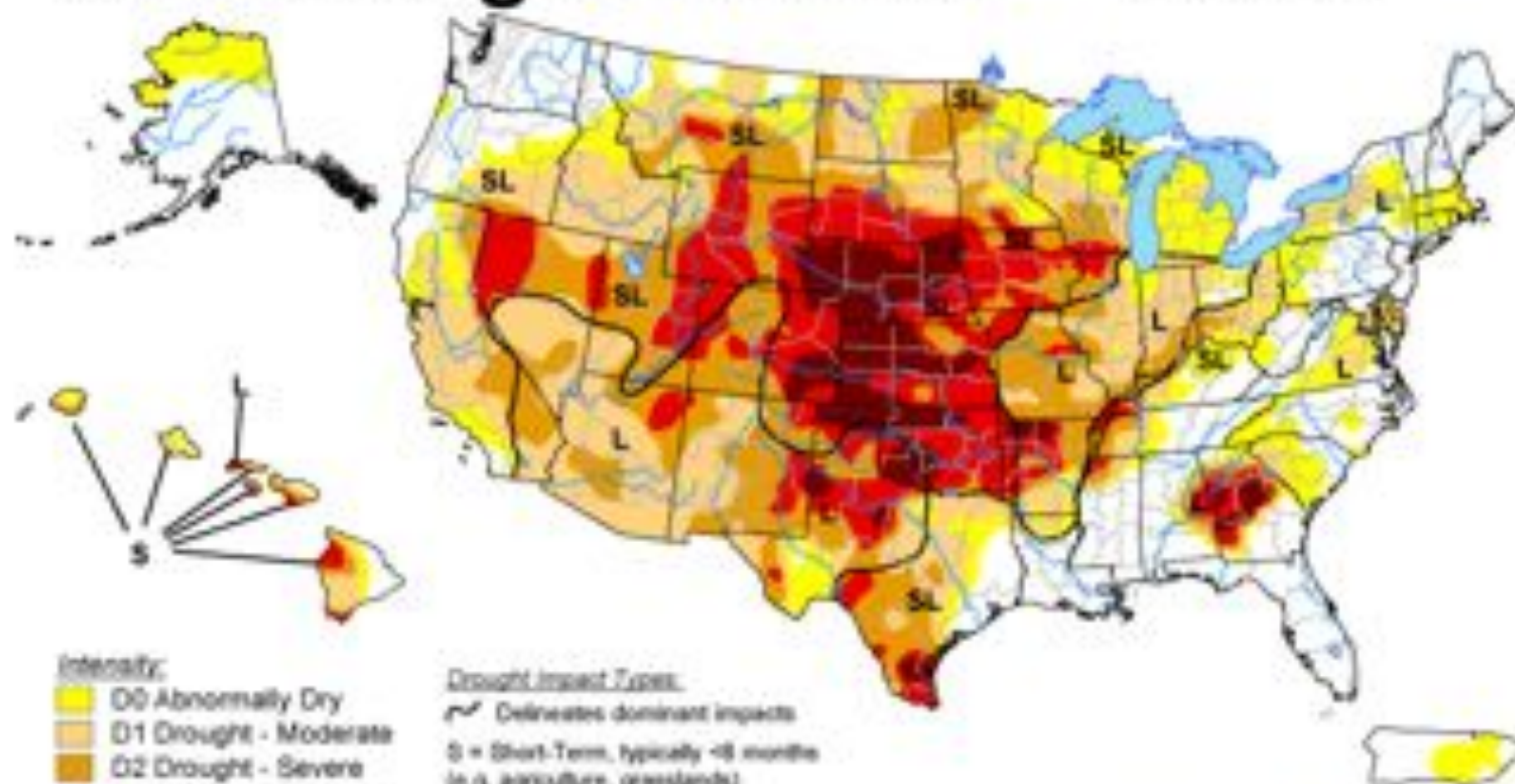




# U.S. Drought Monitor

September 18, 2012

Valid 7 a.m. EDT



## Intensity:

- D0 Abnormally Dry
- D1 Drought - Moderate
- D2 Drought - Severe
- D3 Drought - Extreme
- D4 Drought - Exceptional

## Drought Impact Types:

- ~ Delineates dominant impacts
- S = Short-Term, typically <6 months  
(e.g. agriculture, grasslands)
- L = Long-Term, typically >6 months  
(e.g. hydrology, ecology)

The Drought Monitor focuses on broad-scale conditions.  
Local conditions may vary. See accompanying text summary  
for forecast statements.

<http://droughtmonitor.unl.edu/>



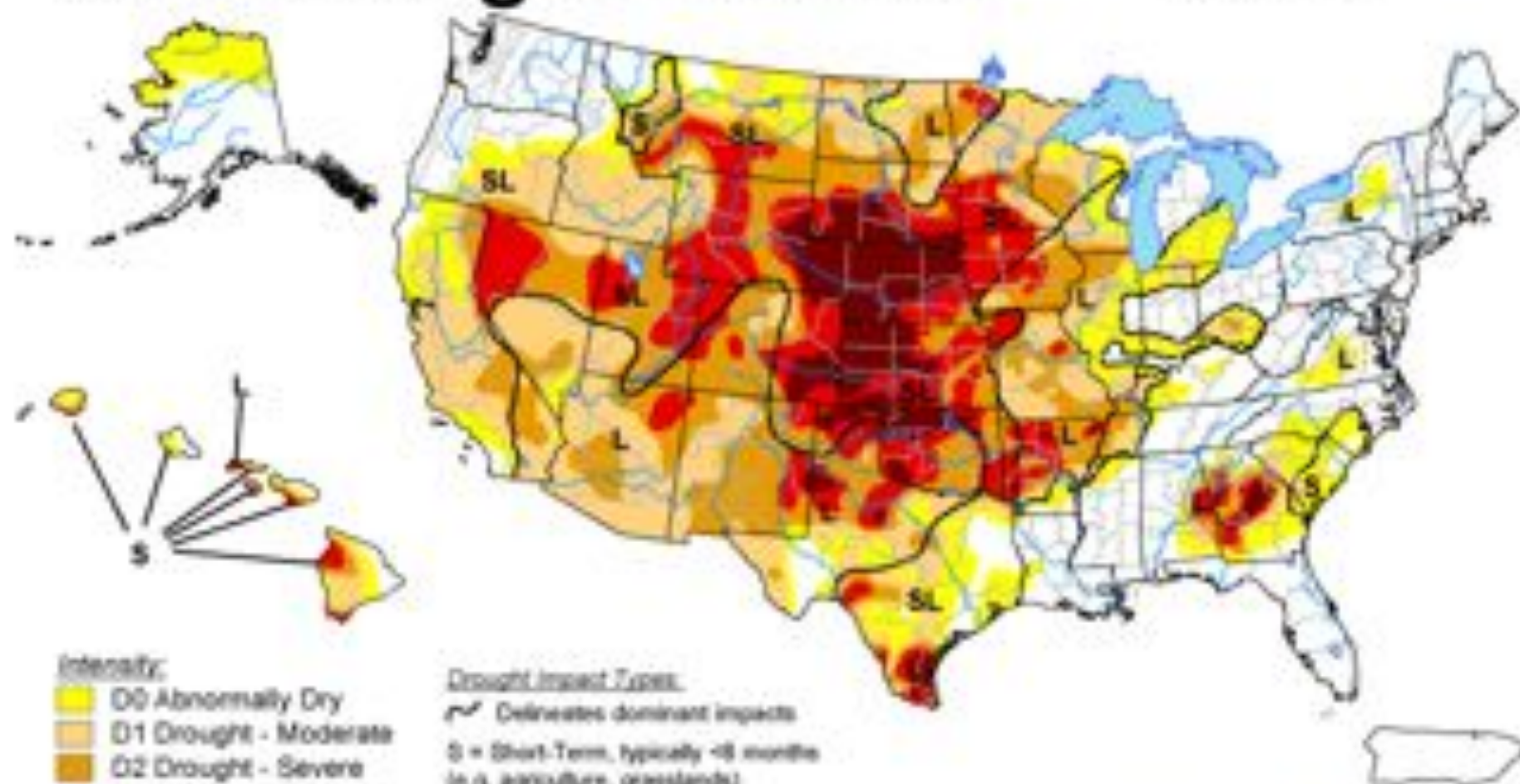
Released Thursday, September 20, 2012

Author: David Simerai, Western Regional Climate Center

# U.S. Drought Monitor

October 30, 2012

Valid 7 a.m. EDT



## Intensity:

- D0 Abnormally Dry
- D1 Drought - Moderate
- D2 Drought - Severe
- D3 Drought - Extreme
- D4 Drought - Exceptional

## Drought Impact Types:

- ~ Delineates dominant impacts
- S = Short-Term, typically <6 months  
(e.g. agriculture, grasslands)
- L = Long-Term, typically >6 months  
(e.g. hydrology, ecology)

The Drought Monitor focuses on broad-scale conditions.  
Local conditions may vary. See accompanying text summary  
for forecast statements.



Released Thursday, November 1, 2012

Author: Michael Brewer/L. Love-Brotak, NOAA/NESDIS/NCDC

<http://droughtmonitor.unl.edu/>



# ***U.S. Drought Monitor Map***

## ***Drought Intensity Categories***



**D0 Abnormally Dry (30%tile)**



**D1 Drought – Moderate (20%tile)**



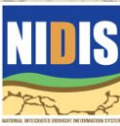
**D2 Drought – Severe (10%tile)**



**D3 Drought – Extreme (5%tile)**



**D4 Drought – Exceptional (2%tile)**








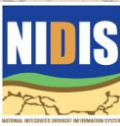


# Percentiles and the U.S. Drought Monitor

## ► Advantages of percentiles:

- Can be applied to any parameter
- Can be used for any length of data record
- Puts drought in historical perspective

- |                            |  |                         |
|----------------------------|--|-------------------------|
| • D4, Exceptional Drought: |    | once per 50+ years      |
| • D3, Extreme Drought:     |    | once per 20 to 50 years |
| • D2, Severe Drought:      |    | once per 10 to 20 years |
| • D1, Moderate Drought:    |  | once per 5 to 10 years  |
| • D0, Abnormally Dry:      |  | once per 3 to 5 years   |



## Integrates Key Drought Indicators:

- Palmer Drought Index
- SPI
- KBDI
- Modeled Soil Moisture
  - NLDAS
- 7-Day Avg. Streamflow
- Precipitation Anomalies

## Growing Season:

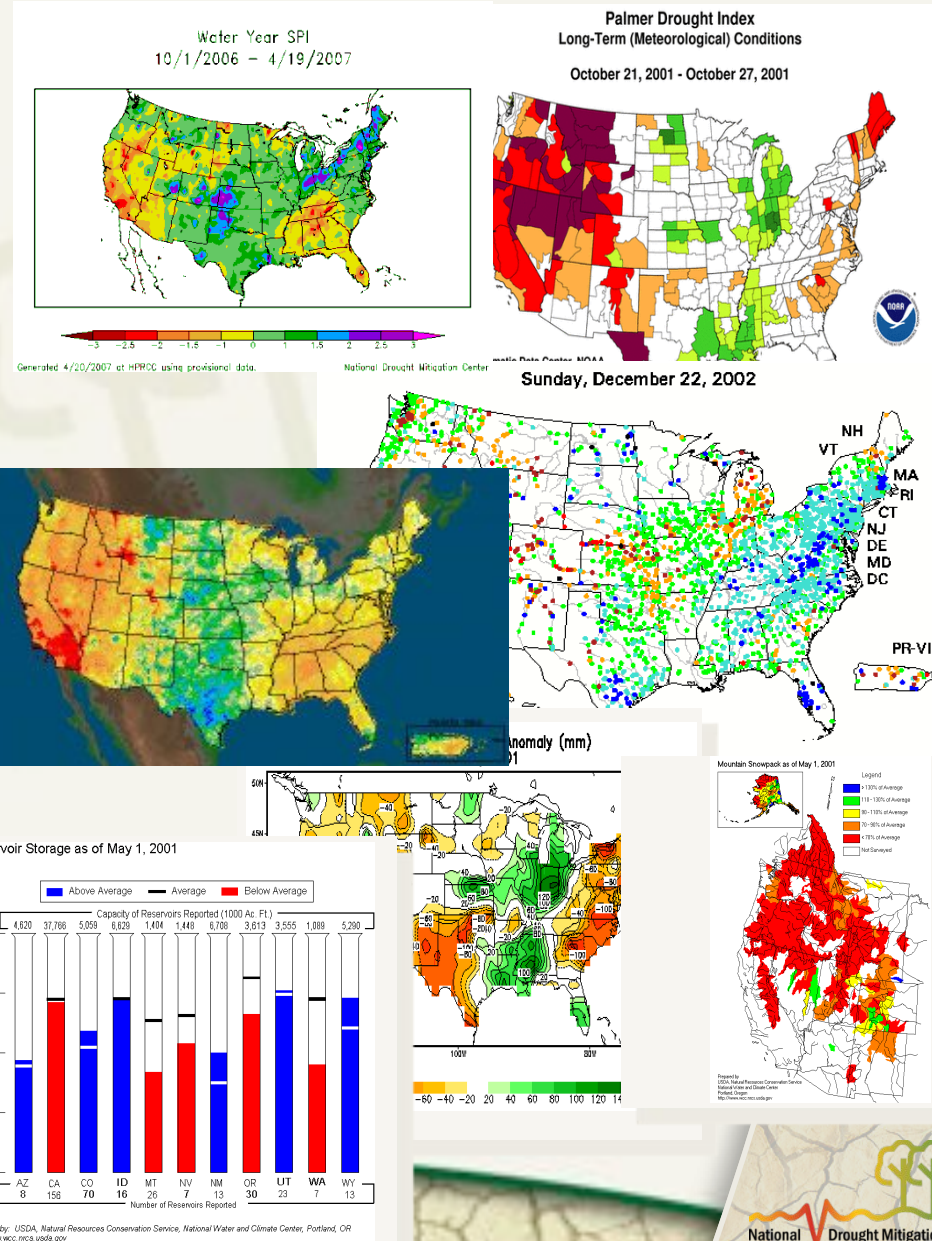
- Crop Moisture Index
- Sat. Veg. Health Index
- VegDRI/ESI/etc.
- Soil Moisture
- Mesonets
  - State/Regional

## In The West:

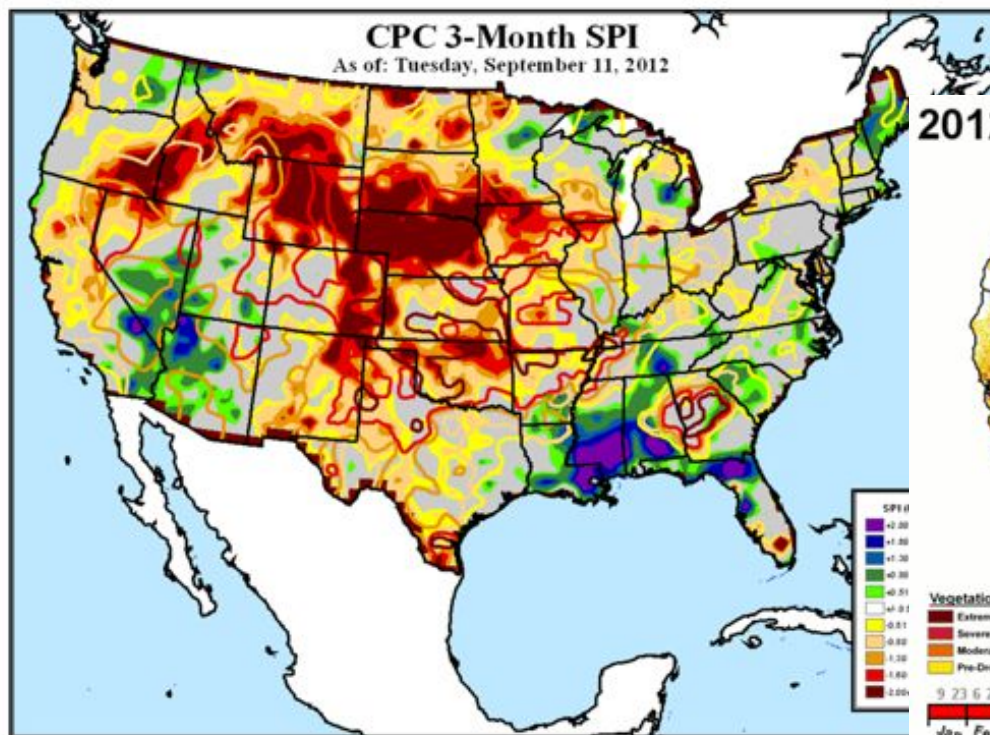
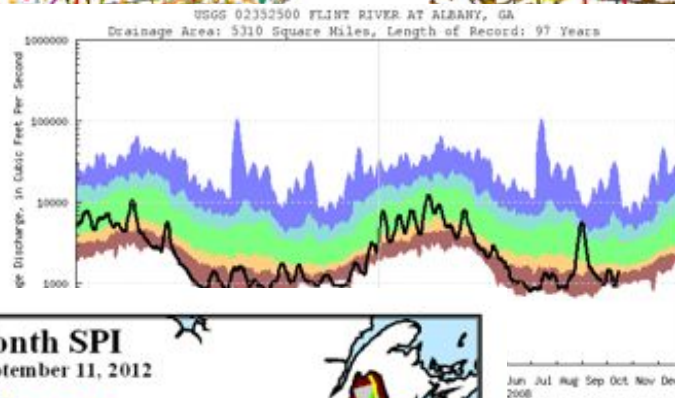
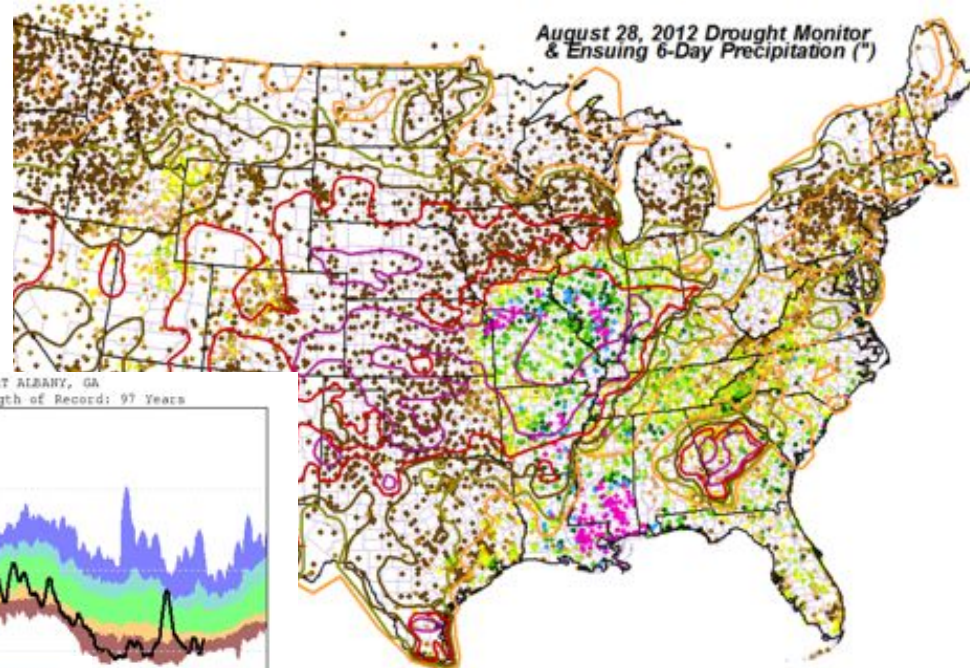
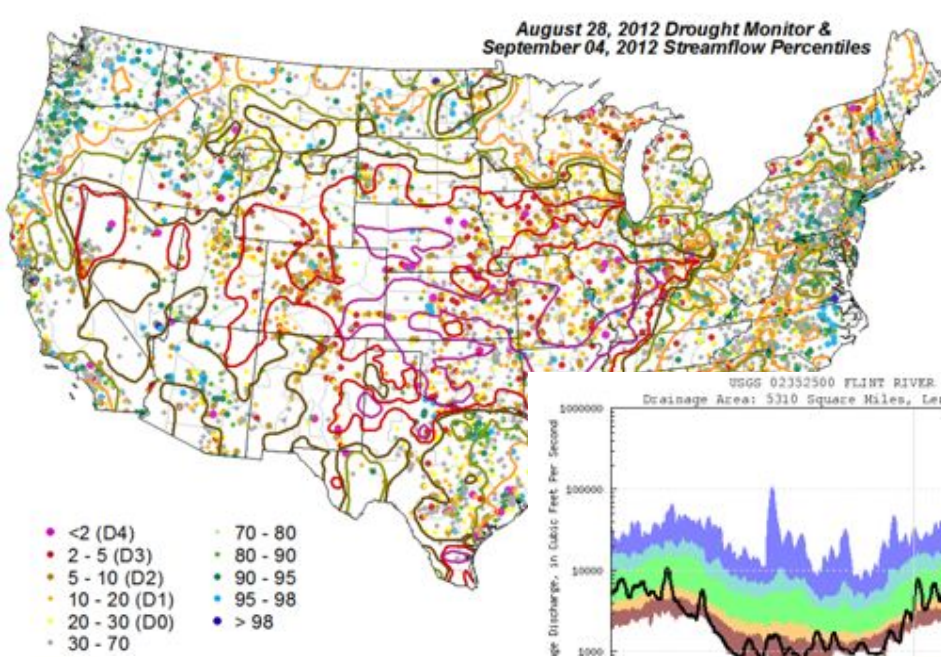
- SWSI
- Reservoir levels
- Snowpack (SNOTEL)
- SWE
- Streamflow

**Created in ArcGIS**

# U.S. Drought Monitor

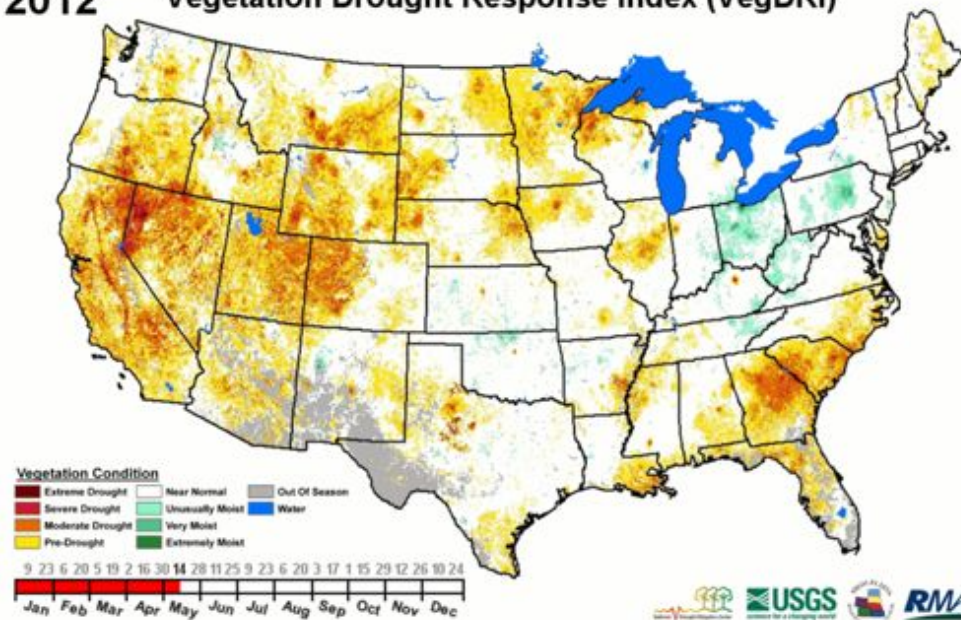




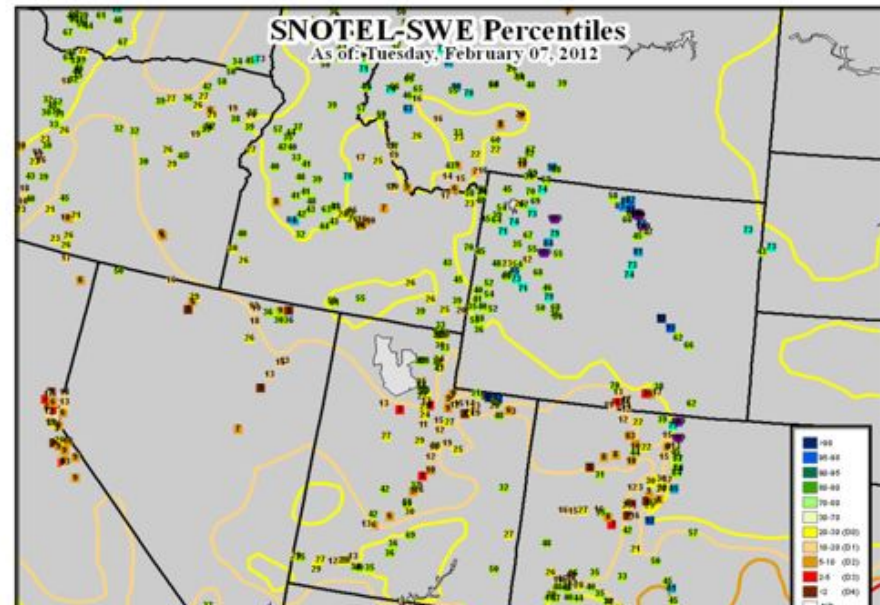
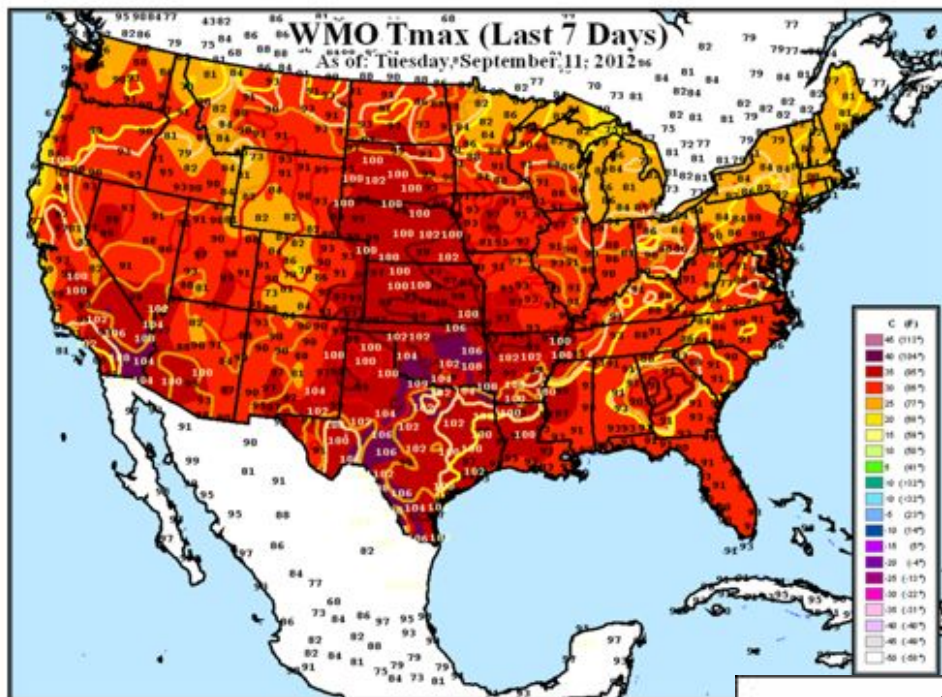


2012

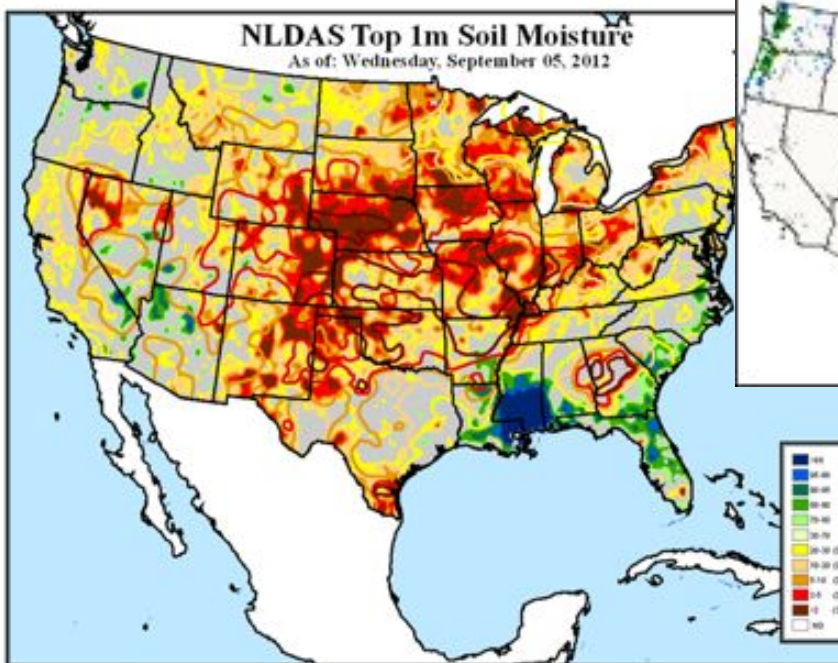
**Vegetation Drought Response Index (VegDRI)**



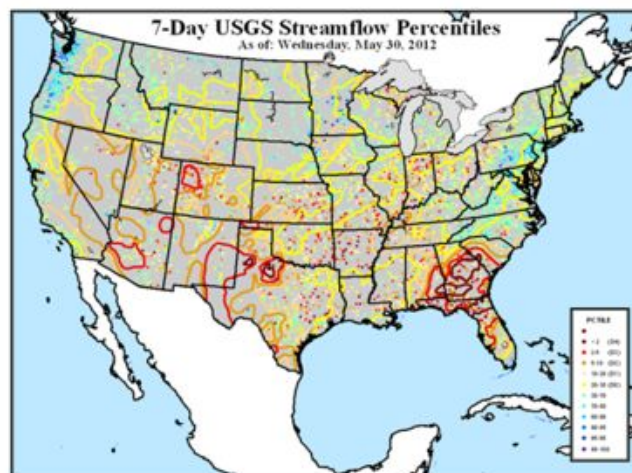
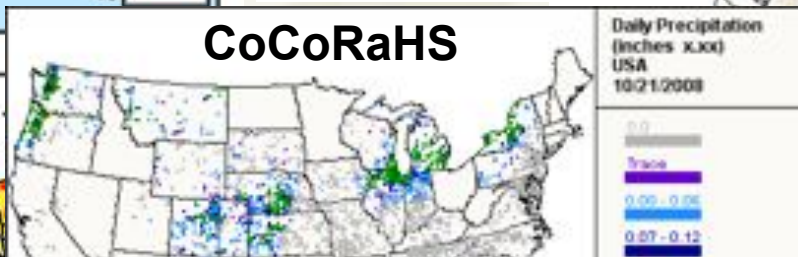




SNOTEL Current Snow Water Equivalent (SWE) Ranking Percentile  
Oct 21, 2008



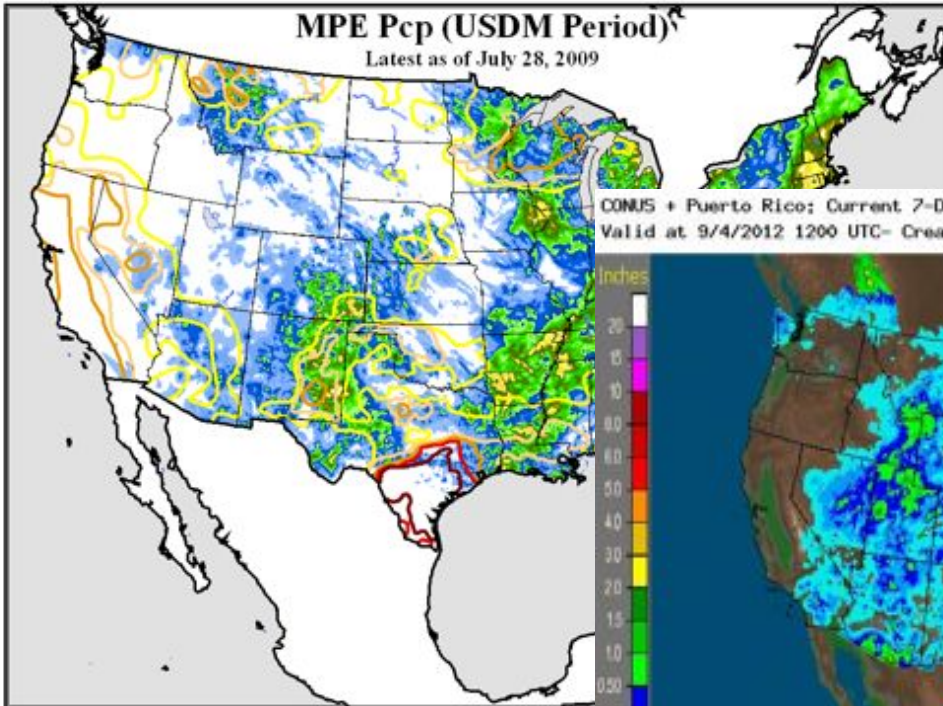
## CoCoRaHS





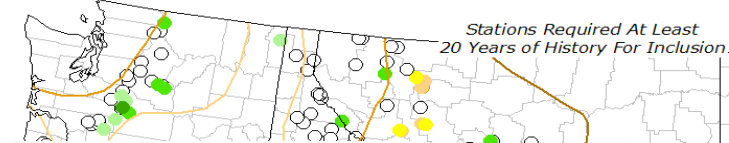
# MPE Pcp (USDM Period)

Latest as of July 28, 2009

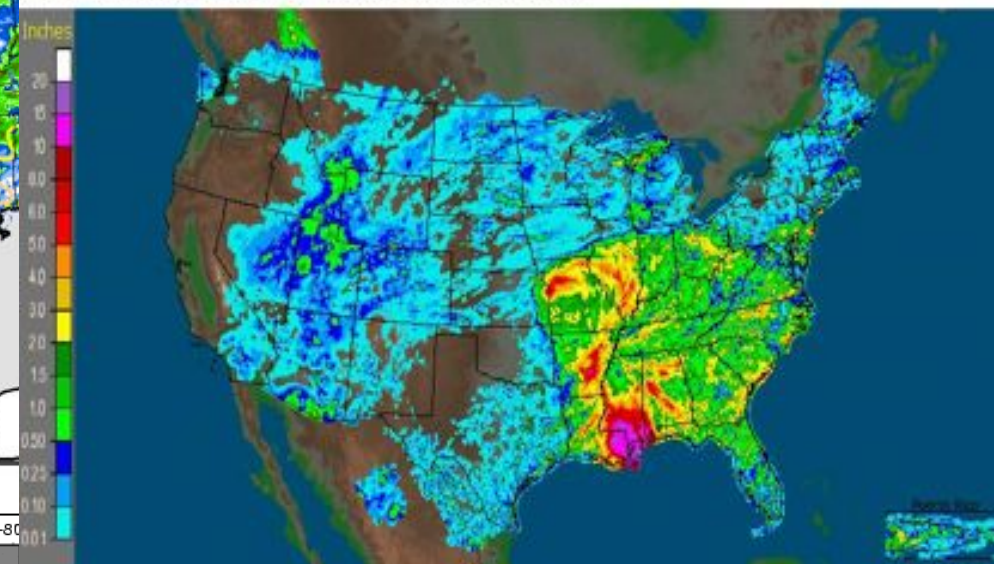


# SNOTEL Water Year Precipitation Percentiles

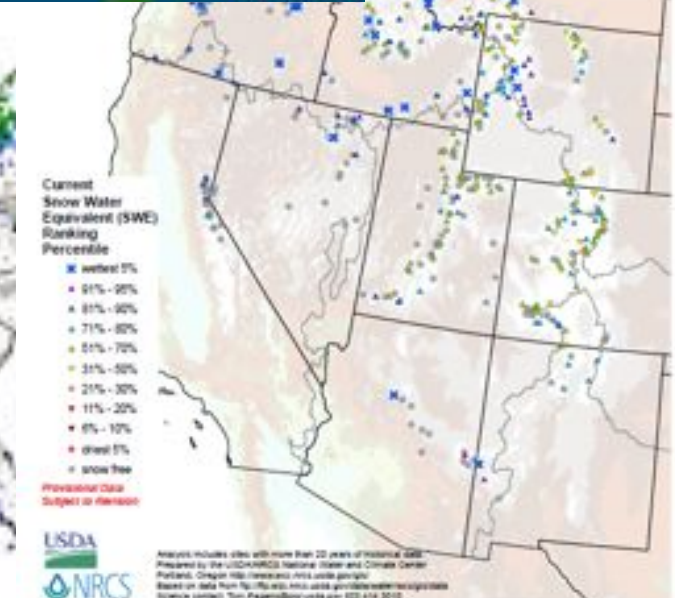
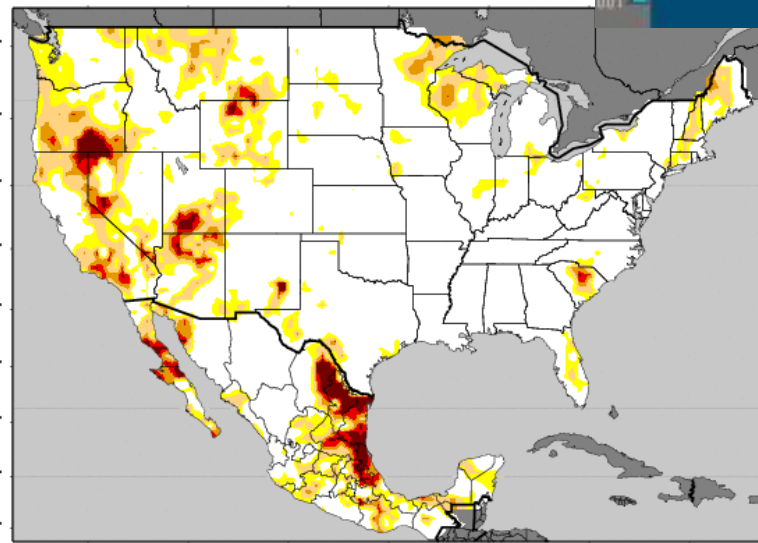
October 1, 2005 - September 12, 2006



CONUS + Puerto Rico; Current 7-Day Observed Precipitation  
Valid at 9/4/2012 1200 UTC- Created 9/4/12 19:38 UTC

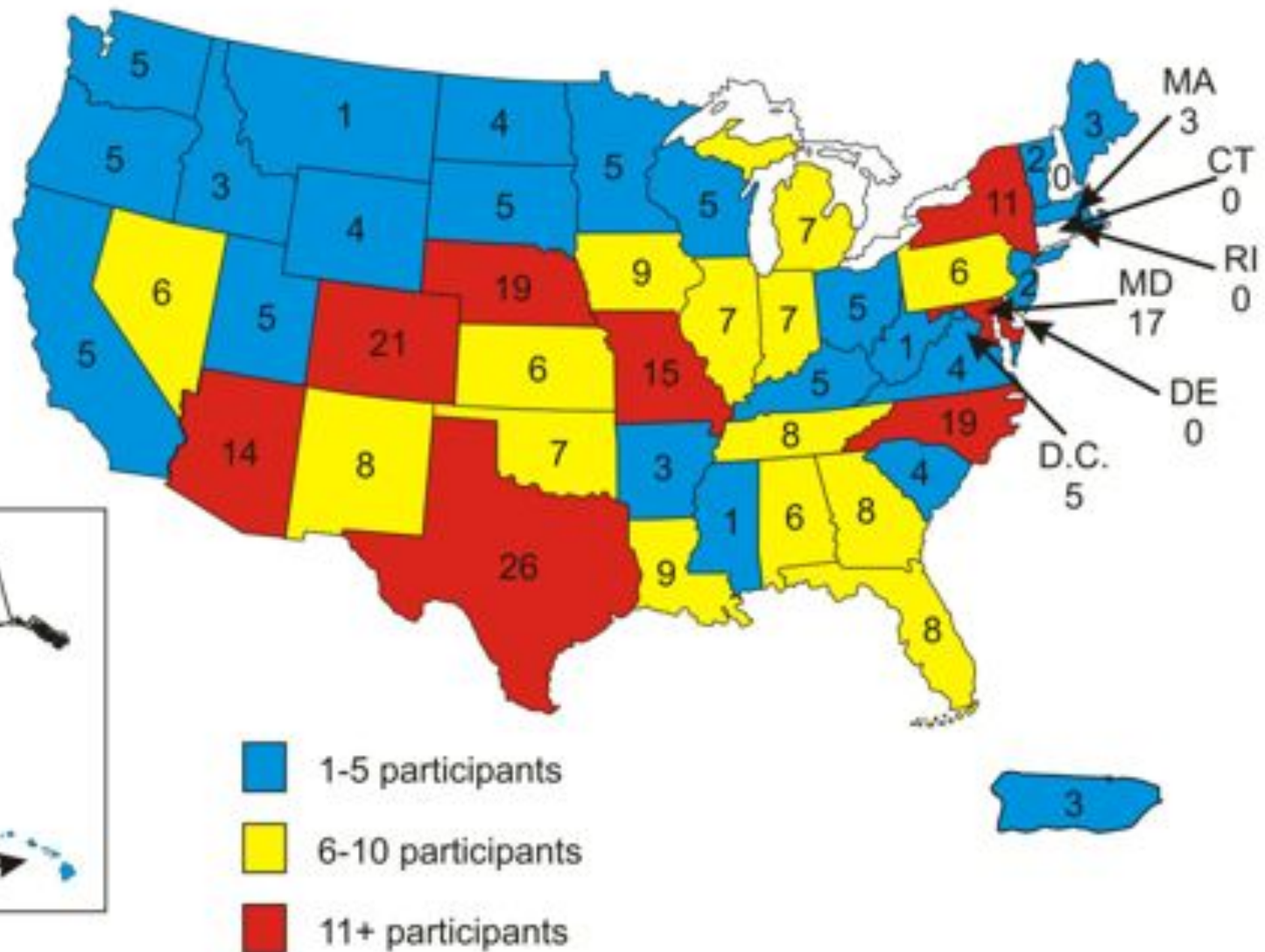


Equivalent (SWE) Ranking Percentile



# USDM Listserve Subscribers

(as of August 10, 2012)

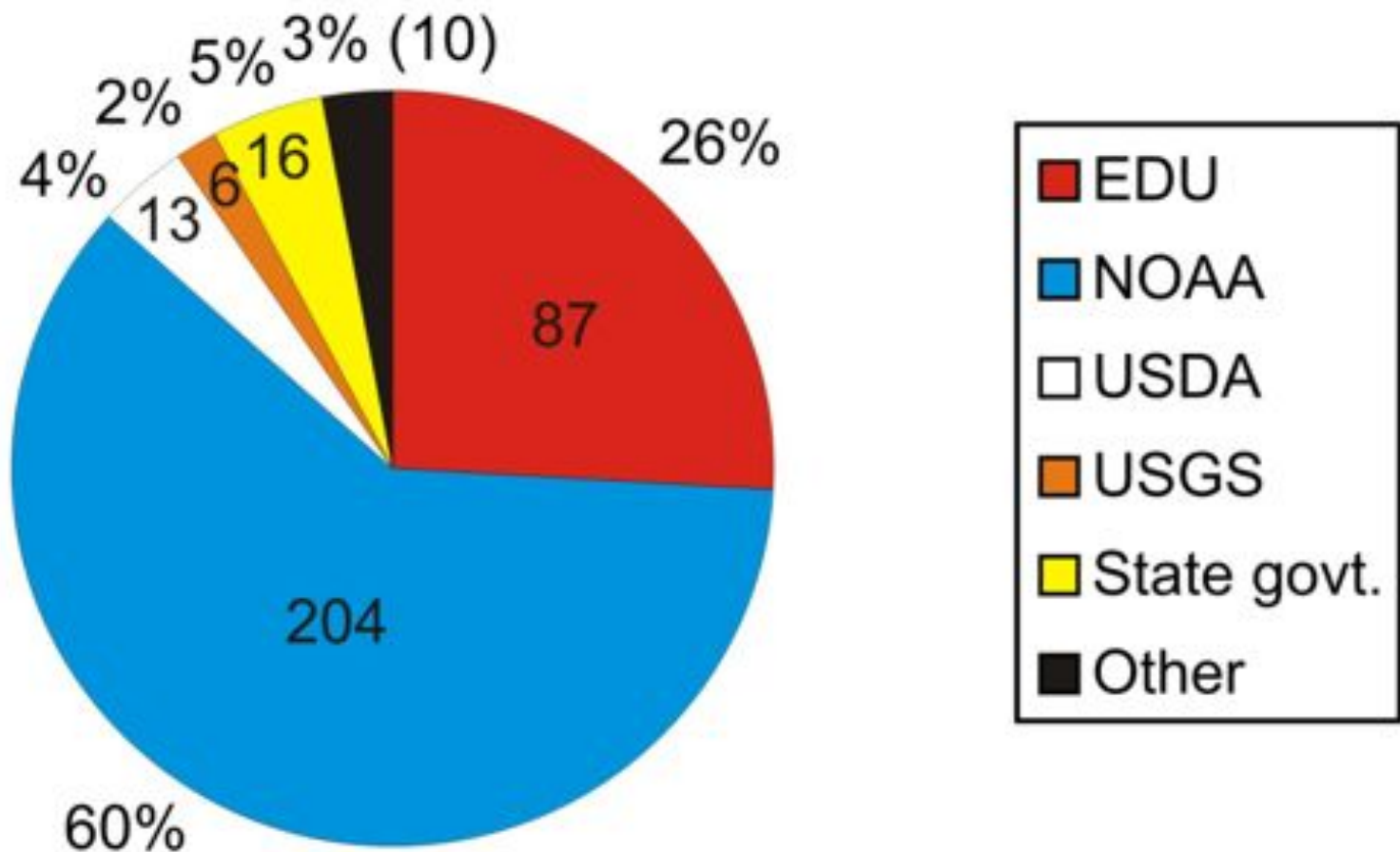


Total: 335 (does not include 1 participant from Canada)



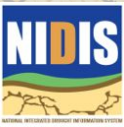
# USDM Listserve Subscribers

(as of August 10, 2012)



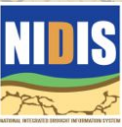
# What has happened since last week?

- Comments from last week's author
- Last week's changes
- Advance comments from experts
- Rain/snow in D0-D4 areas?
- No rain in D0-D4 areas...AND other areas?
- Weighing Short-term vs. Long-term



# Precipitation, Streamflow and Other Indicators

- Typically look at the following suite of products at **30-**, **60-**, and **90-** days, **Year-to-date**, **Water Year-to-date**, **growing season**, **12-** months and **24** months (out to **60** months in the West).

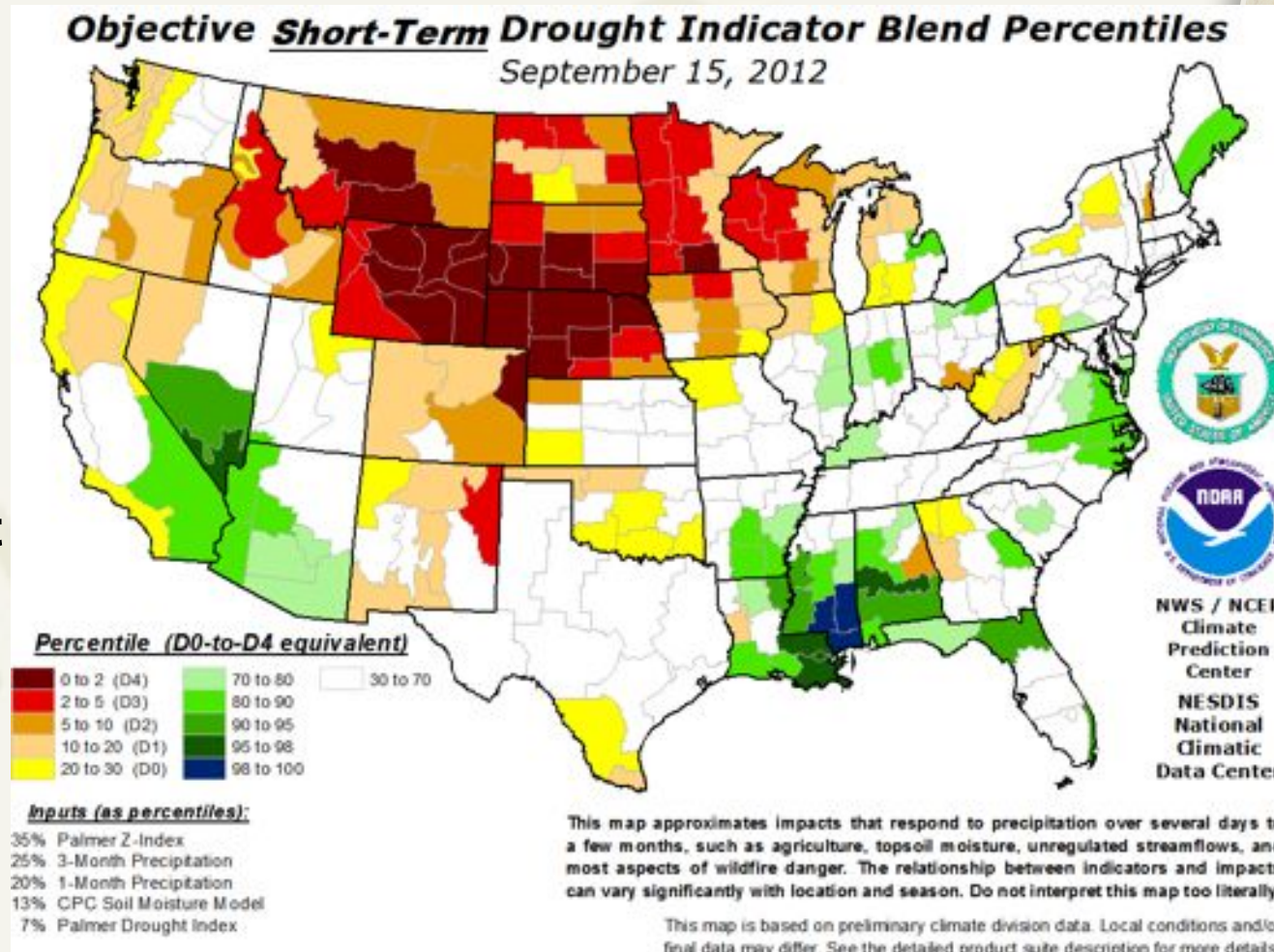




# Objective Blends

## ➤ Short-Term Blend

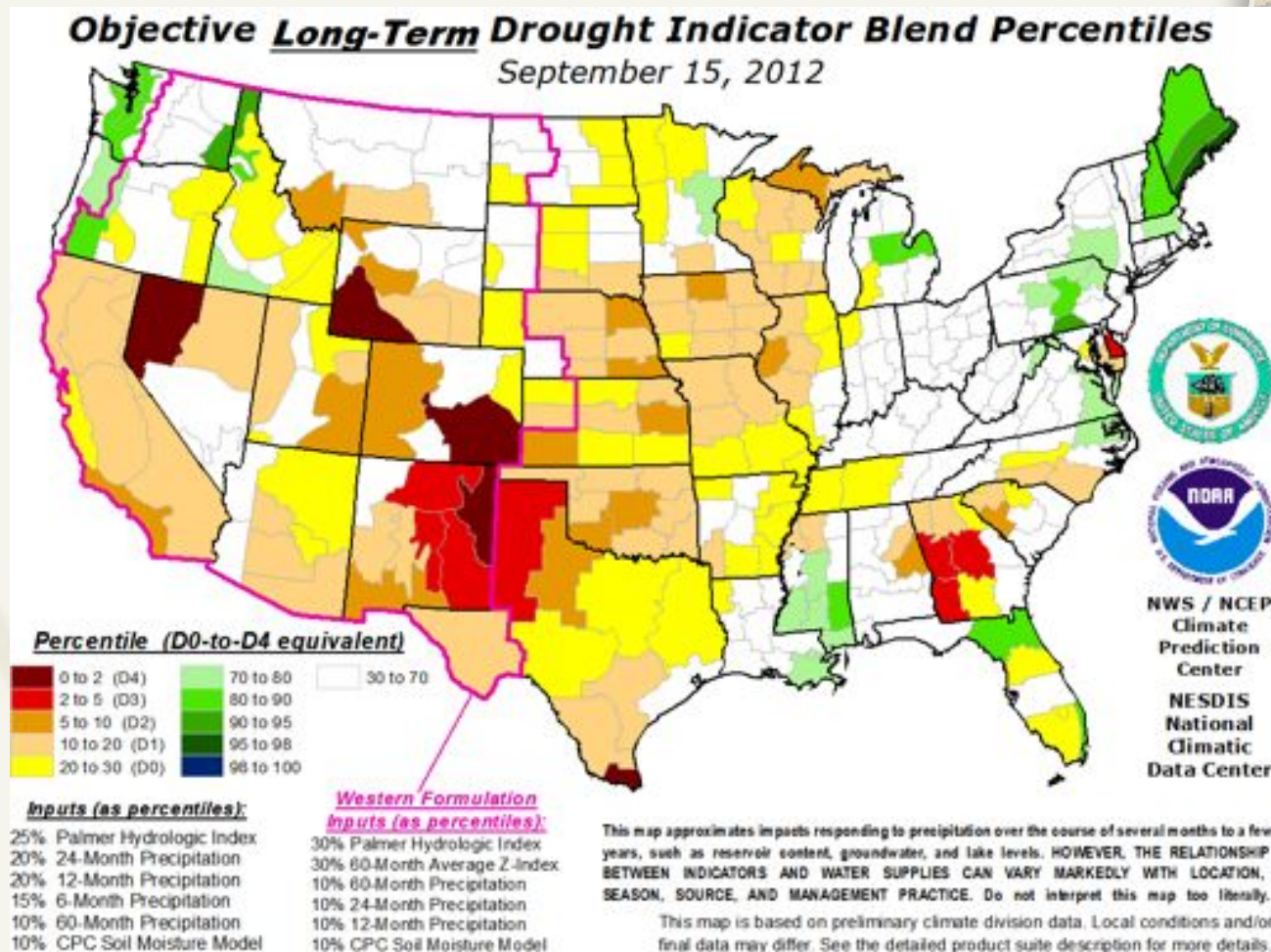
35% Palmer Z Index  
25% 3-Month Precip.  
20% 1-Month Precip.  
13% CPC Soil Model  
7% Palmer Drought Index



# Objective Blends

## ▶ Long-Term Blend

25% Palmer  
Hydrological Index  
20% 24-Month Precip.  
20% 12-Month Precip.  
15% 6-Month Precip.  
10% 60-Month Precip.  
10% CPC Soil Model



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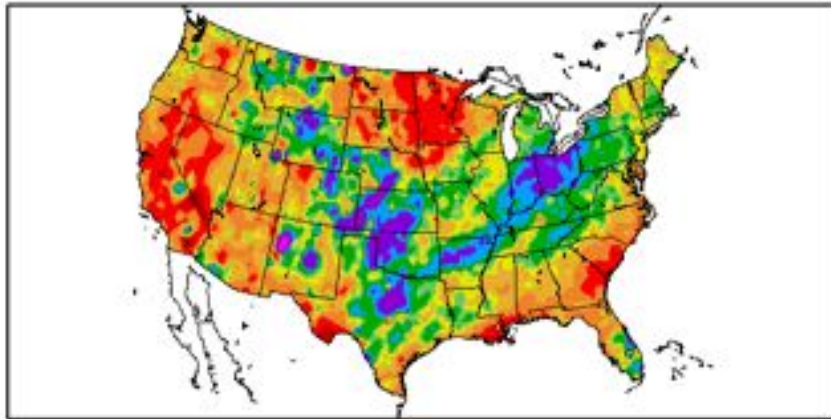
# DROUGHT INDICATOR BLEND AND COMPONENT PERCENTILES -- September 10, 2011

(KEY: D4=0-2 [pink fill] D3=2-5 [red fill] D2=5-10 [brown fill] D1=10-20 [tan fill] D0=20-30 [yellow fill] WET=70-100 [green text])

Climate Division						Drought Blends		Individual Blend Components														
								Precipitation						Palmer Z-index	Palmer Drought Index (PDI)	Palmer Hydro. Drought Index (PHDI)	5-Year Average Z-index	CPC Soil Moisture Model				
ID #	U.S. CD #	State #	State CD #	State Name	CD Name	Short Term	Long Term	1-Month	3-Month	6-Month	1-Year	2-Year	5-Year									
0101	1	1	1	Alabama	Northern Valley	94.6	82.4	89.5	89.3	93.4	77.5	76.7	31.9	89.9	77.1	73.0	36.1	89.8				
0102	2	1	2	Alabama	Appalachian Mountain	97.0	88.5	99.5	92.3	95.4	71.6	86.5	37.1	94.4	93.5	93.0	17.4	100.0				
0103	3	1	3	Alabama	Upper Plains	77.6	54.6	86.3	54.4	88.6	46.7	74.4	34.7	75.7	54.5	17.6	36.4	86.8				
0104	4	1	4	Alabama	Eastern Valley	57.9	25.7	73.9	30.3	38.8	20.4	44.0	16.5	41.7	42.3	13.4	3.4	24.3				
0105	5	1	5	Alabama	Piedmont Plateau	9.5	11.4	18.3	15.2	7.0	4.3	52.7	11.2	14.3	12.3	7.8	15.9	3.5				
0106	6	1	6	Alabama	Prairie	54.5	15.2	70.1	49.3	15.9	9.3	38.2	21.5	62.0	49.3	16.0	20.2	18.8				
0107	7	1	7	Alabama	Coastal Plain	10.8	8.2	25.5	24.2	4.4	3.7	31.4	41.3	29.3	4.5	9.2	29.8	12.5				
0108	8	1	8	Alabama	Gulf	78.8	19.2	81.5	83.8	18.8	5.1	46.1	43.0	90.1	44.3	19.7	41.8	56.3				
0201	9	2	1	Arizona	Northwest	17.1	26.9	18.8	61.7	17.8	69.0	83.3	9.8	18.3	37.8	46.1	15.3	25.8				
0202	10	2	2	Arizona	Northeast	28.0	17.6	28.0	53.2	21.7	21.0	69.3	34.3	23.6	16.8	20.2	17.3	21.3				
0203	11	2	3	Arizona	North-Central	3.4	0.7	6.0	23.0	2.1	10.2	13.5	1.7	1.3	9.4	9.5	6.1	2.5				
0204	12	2	4	Arizona	East-Central	25.2	14.6	17.2	71.1	25.8	17.4	51.9	43.7	38.2	18.2	13.6	22.5	18.3				
0205	13	2	5	Arizona	Southwest	55.7	54.7	34.5	91.5	67.3	43.9	88.0	37.8	30.3	65.8	70.5	37.5	53.8				
0206	14	2	6	Arizona	South-Central	9.3	1.4	8.9	29.8	9.9	3.7	14.2	9.8	13.7	6.3	8.3	3.9	2.3				
0207	15	2	7	Arizona	Southeast	42.5	8.5	47.3	64.1	42.5	7.0	24.4	18.8	8.3	3.8	9.2	9.6	62.5				
0208	16	3	1	Arkansas	Northwest	11.7	50.6	56.4	4.5	93.3	76.3	78.0	95.0	7.2	5.5	6.2	89.9	25.8				
0209	17	3	2	Arkansas	North-Central	15.5	64.8	35.1	8.4	95.9	70.2	94.9	100.0	18.8	18.8	18.8	100.0	33.5				
0210	18	3	3	Arkansas	Northeast	19.2	54.9	16.1	7.3	65.9	53.9	77.5	94.8	13.1	6.2	7.4	92.3	31.3				
0211	19	3	4	Arkansas	West-Central	13.5	38.4	42.8	4.2	70.5	29.3	57.8	98.8	10.7	8.1	7.1	92.7	17.5				
0212	20	3	5	Arkansas	Central	33.4	55.2	71.5	22.8	76.7	38.4	76.0	100.0	22.8	21.6	14.0	94.3	32.5				
0213	21	3	6	Arkansas	East-Central	30.8	54.8	42.4	27.0	82.4	51.1	87.8	75.3	10.7	18.8	18.9	93.8	95.8				
0214	22	3	7	Arkansas	Southwest	2.1	16.7	11.5	3.8	27.4	6.7	29.6	64.4	6.7	6.0	9.8	45.4	3.0				
0215	23	3	8	Arkansas	South-Central	21.4	15.8	55.6	14.9	25.5	3.3	38.7	75.0	26.8	1.3	3.3	88.4	17.5				
0216	24	3	9	Arkansas	Southeast	22.5	8.2	55.3	19.7	13.4	6.9	25.0	48.5	17.1	6.0	9.0	54.3	21.3				
0301	25	4	1	California	North Coast Basin	28.9	38.7	6.1	37.2	49.8	60.0	64.7	21.8	40.7	42.8	46.8	18.1	81.3				
0302	26	4	2	California	Sacramento Basin	51.3	45.4	25.5	55.6	66.1	81.3	78.2	28.0	48.0	81.3	70.0	33.7	96.3				
0303	27	4	3	California	Northeast Interior Basin	24.7	52.7	3.4	63.7	73.9	87.9	78.3	24.7	17.5	32.8	38.1	23.7	85.0				
0304	28	4	4	California	Central Coast Basin	86.1	81.0	73.4	93.1	81.6	89.5	85.2	46.8	26.6	23.7	49.4	42.8	91.3				
0305	29	4	5	California	San Joaquin Basin	92.7	71.2	100.0	99.5	75.5	94.0	91.0	41.8	54.9	48.8	83.4	39.0	98.8				
0306	30	4	6	California	South Coast Basin	48.5	35.1	39.3	26.7	31.3	81.0	79.7	21.6	43.1	34.4	34.4	8.7	75.6				
0307	31	4	7	California	Southeast Desert Basins	56.2	35.6	35.4	70.8	22.5	43.4	49.3	5.5	51.1	46.4	53.3	18.8	58.8				
Climate Division						Drought Blends		Individual Blend Components														
								Precipitation						Palmer Z-index	Palmer Drought Index (PDI)	Palmer Hydro. Drought Index (PHDI)	5-Year Average Z-index	CPC Soil Moisture Model				
ID #	U.S. CD #	State #	State CD #	State Name	CD Name	Short Term	Long Term	1-Month	3-Month	6-Month	1-Year	2-Year	5-Year									
0401	32	5	1	Colorado	Arkansas Basin	4.1	0.7	14.8	13.1	11.2	6.3	23.8	34.8	4.1	0.0	0.0	23.3	3.4				
0402	33	5	2	Colorado	Colorado Basin	40.6	46.6	48.8	67.8	82.8	78.0	67.4	70.3	29.4	32.2	34.8	51.8	70.8				
0403	34	5	3	Colorado	Kansas Basin	8.5	54.7	7.8	18.4	72.5	46.7	67.7	91.5	5.8	28.7	29.4	73.5	41.3				



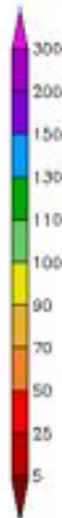
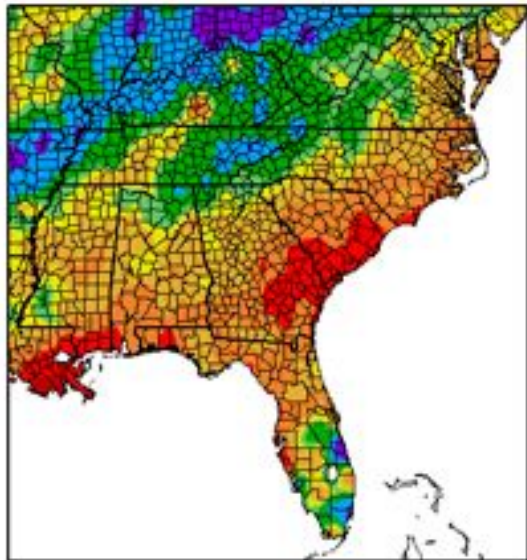
Percent of Normal Precipitation (%)  
10/1/2011 – 2/7/2012



Generated 2/8/2012 at HPRDC using provisional data.

Regional Climate Centers

Percent of Normal Precipitation (%)  
10/1/2011 – 2/7/2012

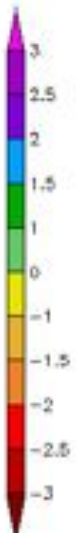
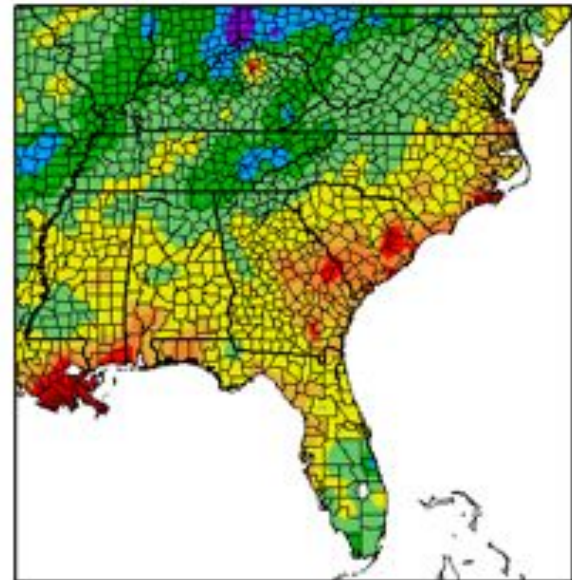


Generated 2/8/2012 at HPRDC using provisional data.

Regional Climate Centers

**Applied  
Climate  
Information  
System (ACIS)  
is a key player.....**

Water Year SPI  
10/1/2011 – 2/7/2012

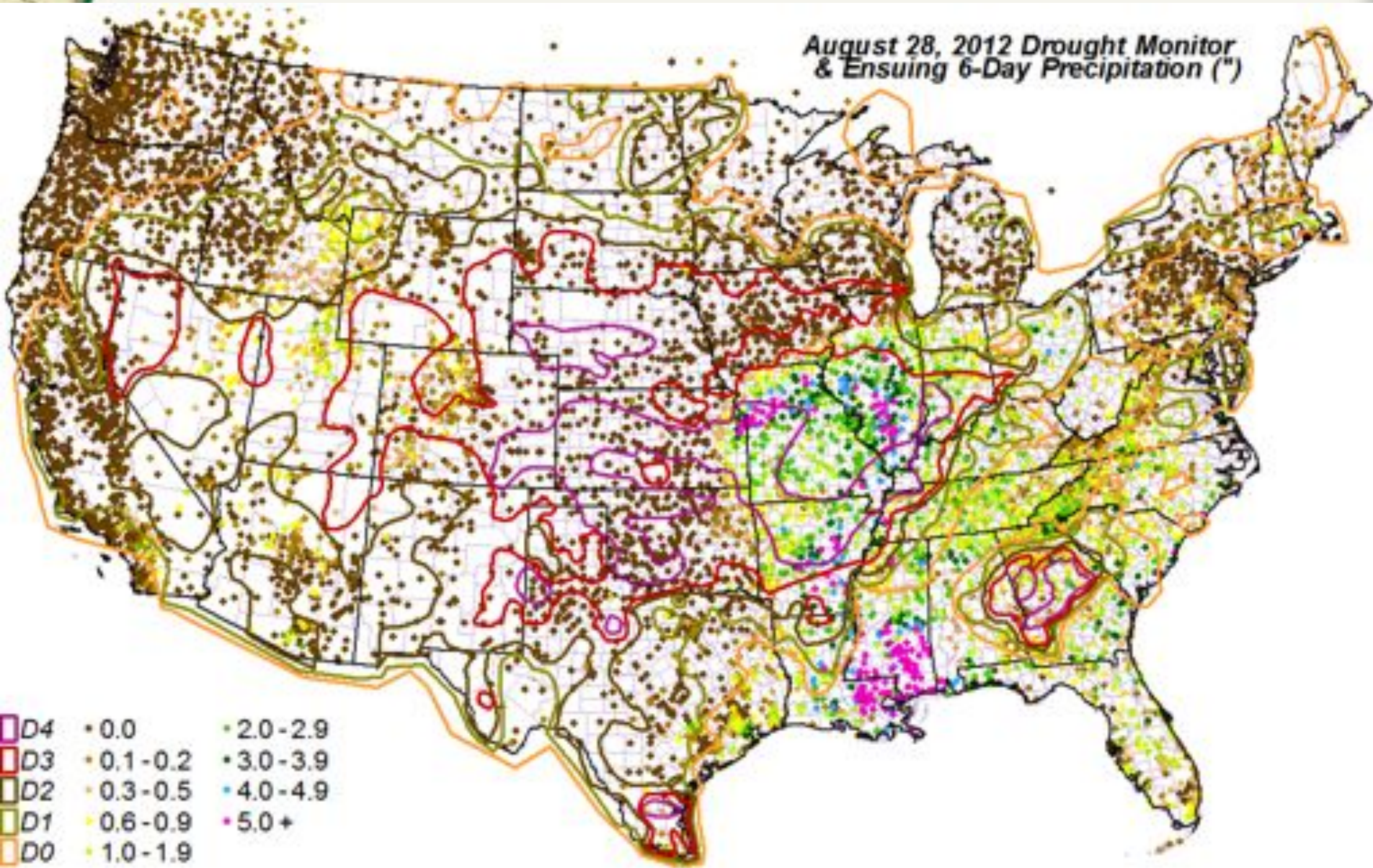


Generated 2/8/2012 at HPRDC using provisional data.

Regional Climate Centers

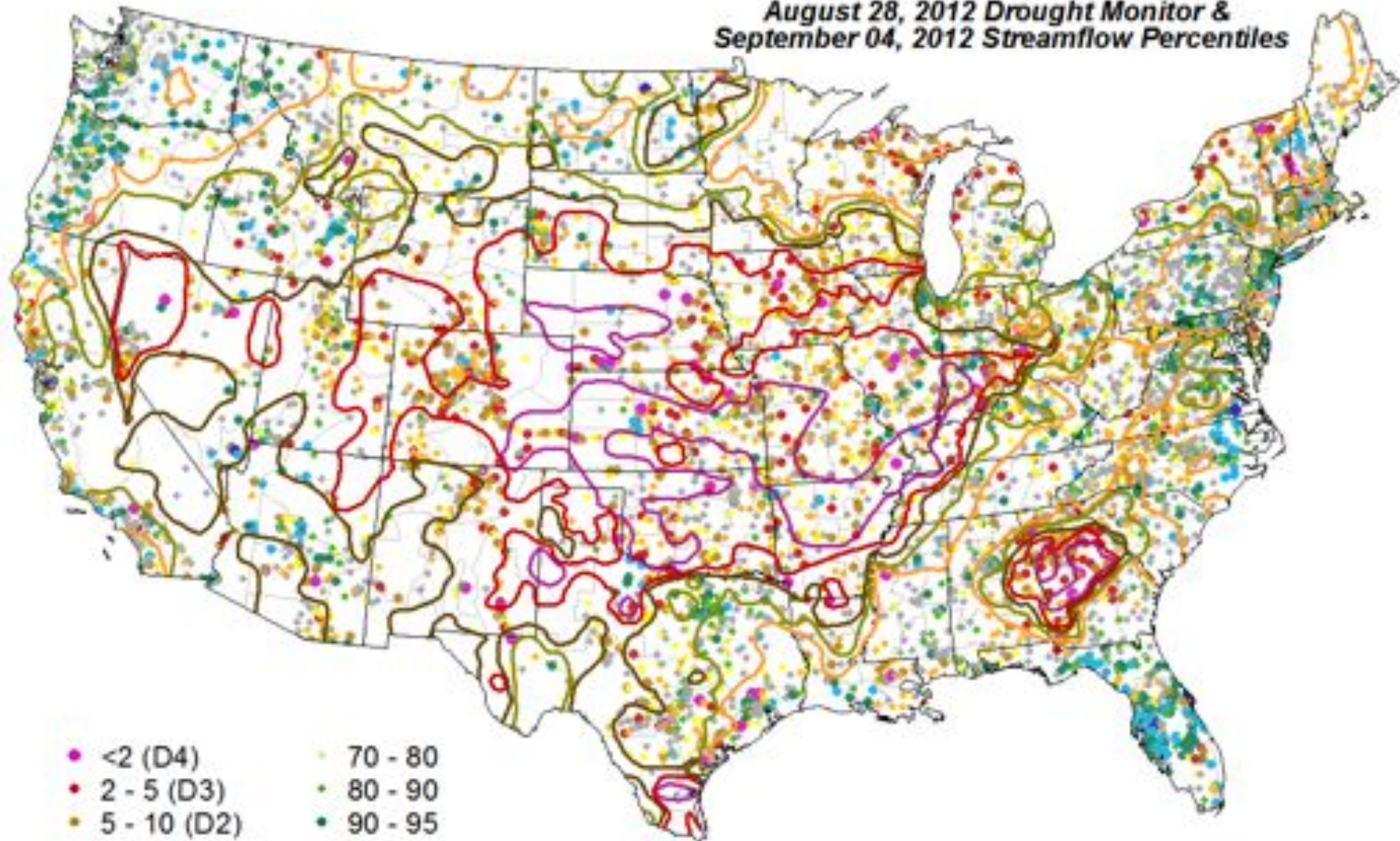


August 28, 2012 Drought Monitor  
& Ensuing 6-Day Precipitation (")





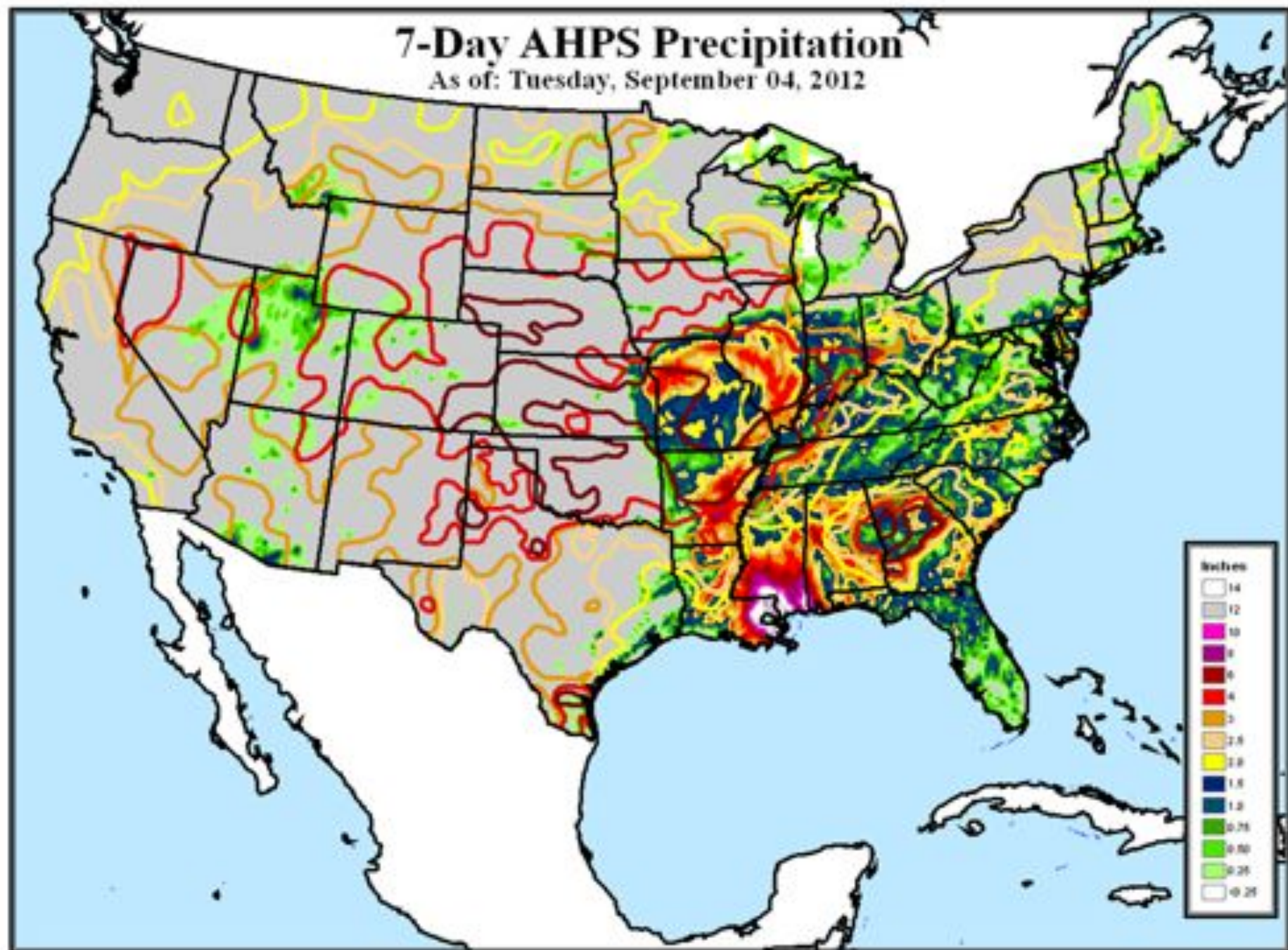
**August 28, 2012 Drought Monitor &  
September 04, 2012 Streamflow Percentiles**





# 7-Day AHPS Precipitation

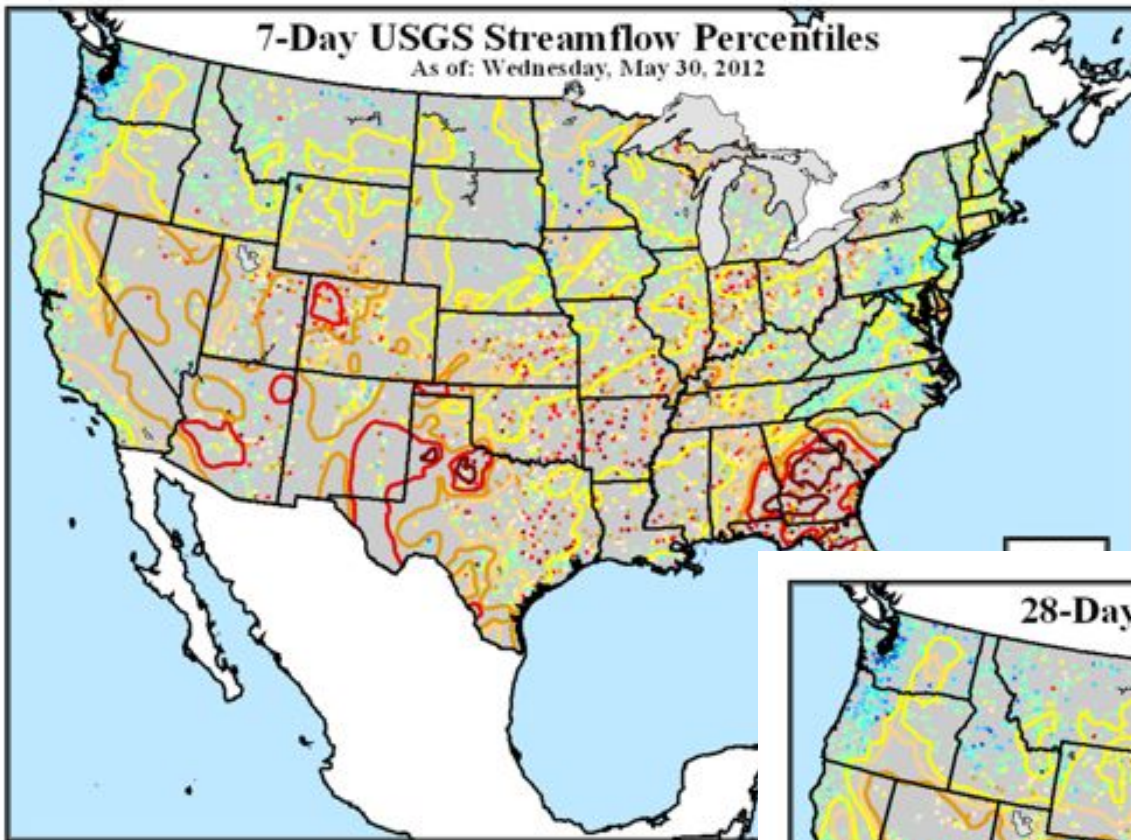
As of: Tuesday, September 04, 2012





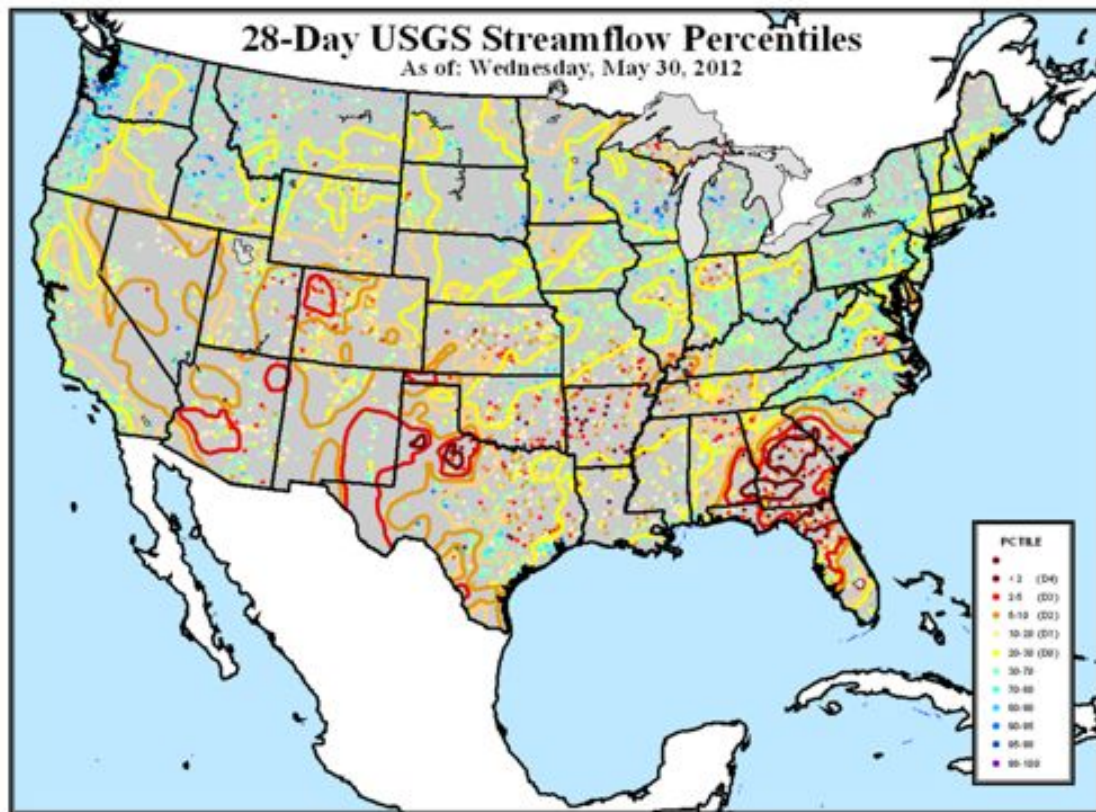
# 7-Day USGS Streamflow Percentiles

As of: Wednesday, May 30, 2012



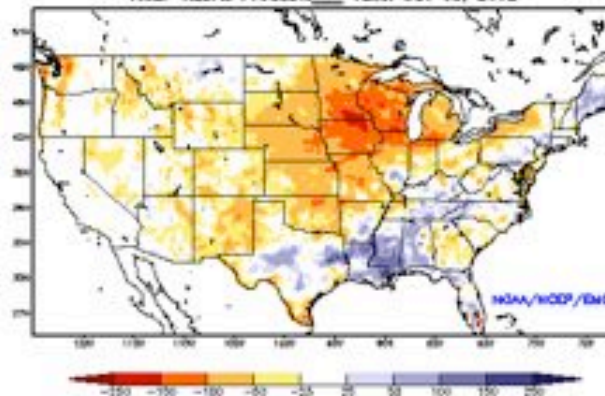
# 28-Day USGS Streamflow Percentiles

As of: Wednesday, May 30, 2012



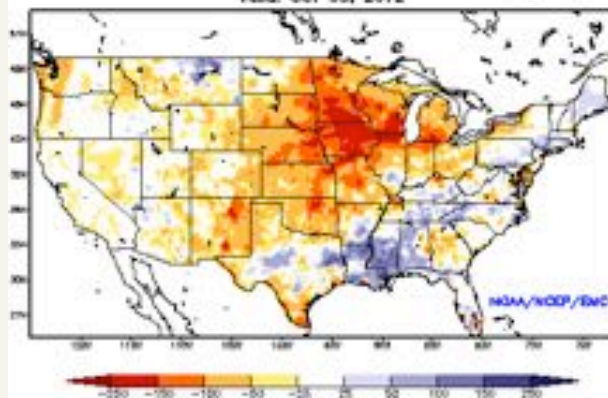


Ensemble-Mean - Current Total Column Soil Moisture Anomaly (mm)  
NCEP NLDAS Products Valid: OCT 05, 2012



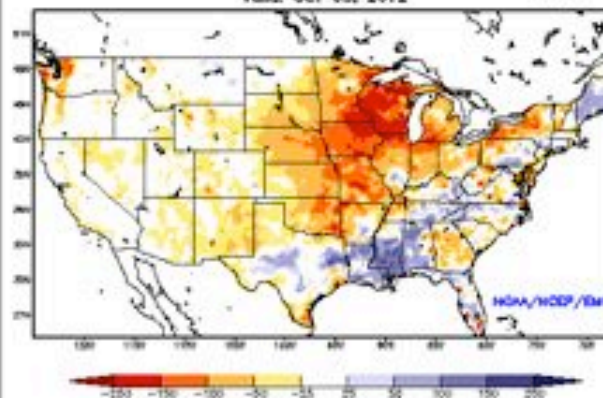
NOAH LSM OUTPUT:

NCEP Noah - Current Total Column Soil Moisture Anomaly (mm)  
Valid: OCT 05, 2012



MOSAIC LSM OUTPUT:

NASA Mosaic - Current Total Column Soil Moisture Anomaly (mm)  
Valid: OCT 05, 2012



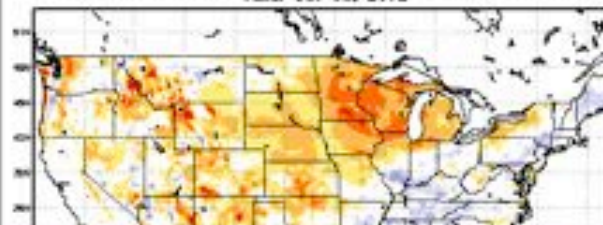
SAC LSM OUTPUT:

DHD SAC - Current Total Column Soil Moisture Anomaly (mm)  
Valid: OCT 05, 2012



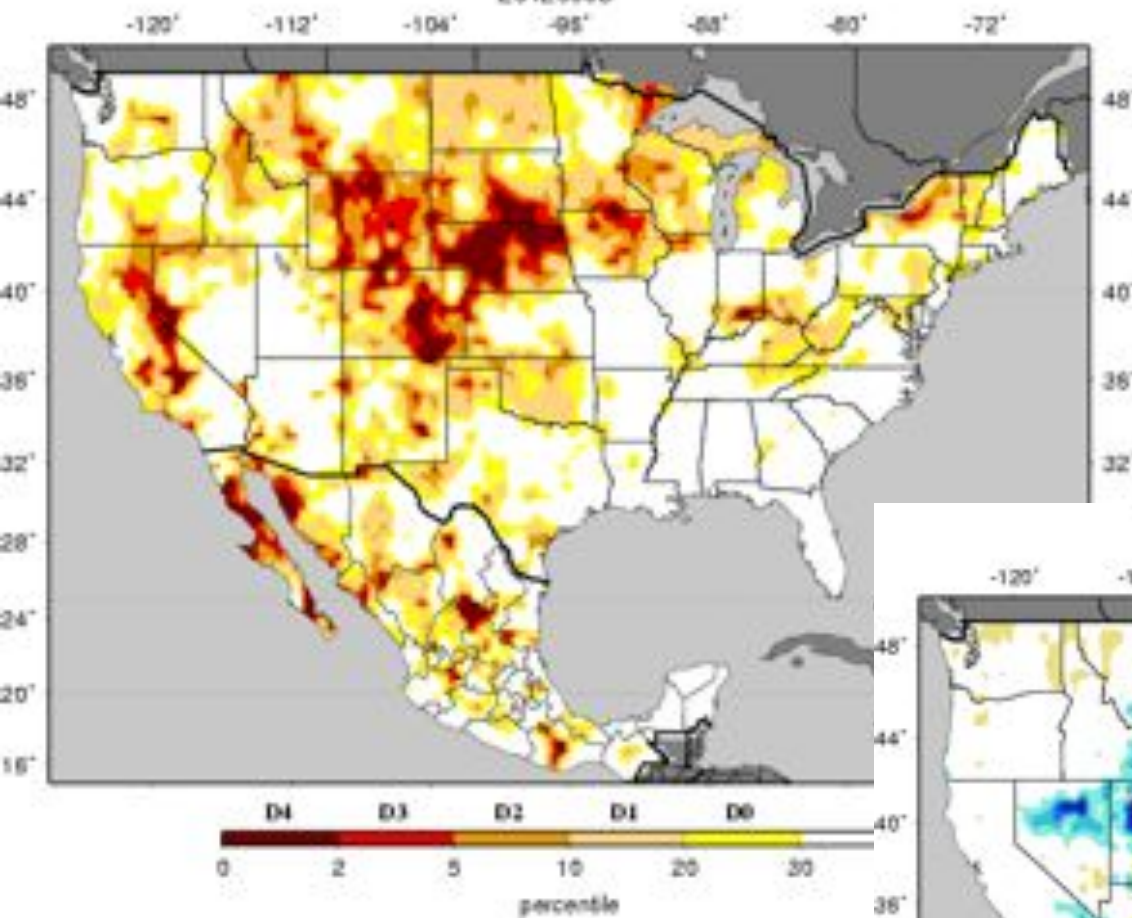
VIC LSM OUTPUT:

Princeton VIC - Current Total Column Soil Moisture Anomaly (mm)  
Valid: OCT 05, 2012

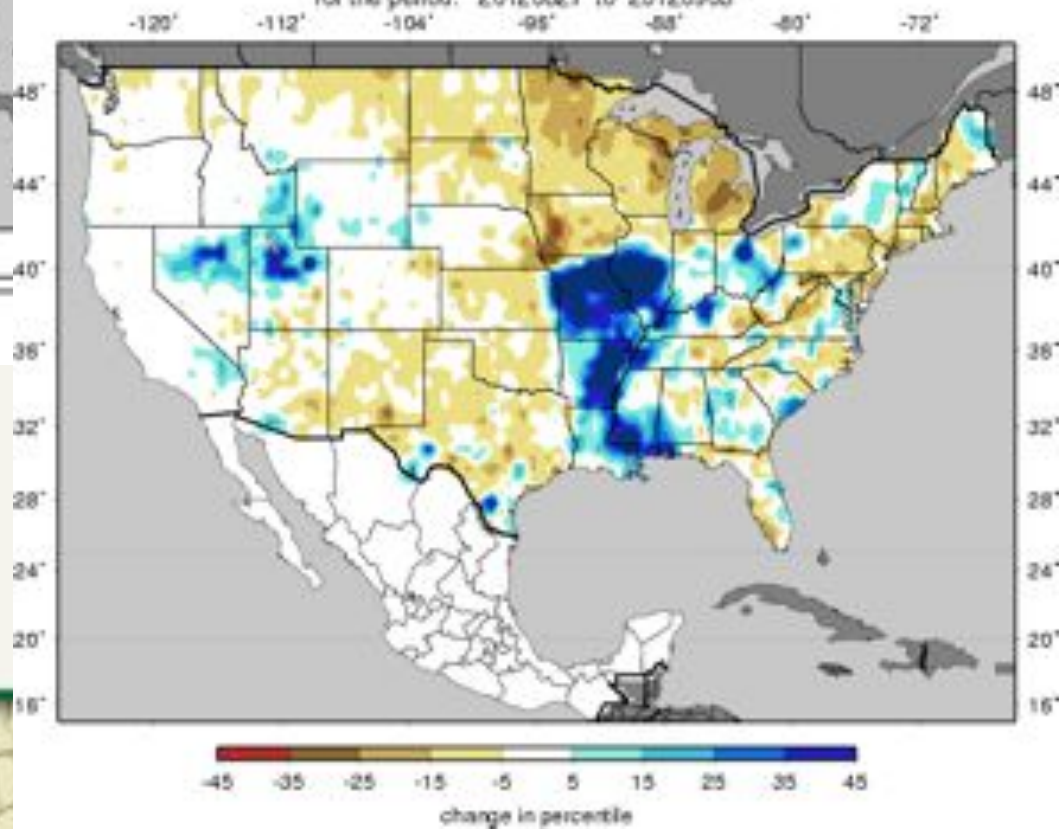




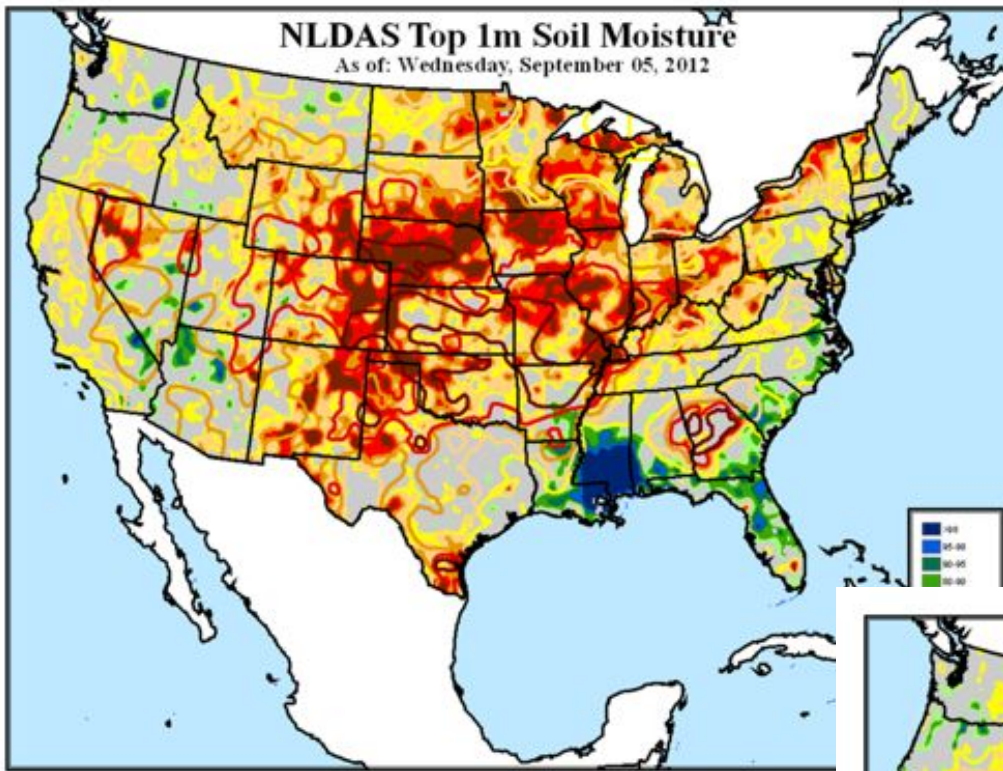
VIC Soil Moisture Percentiles (wrt/ 1916-2004)  
20120903



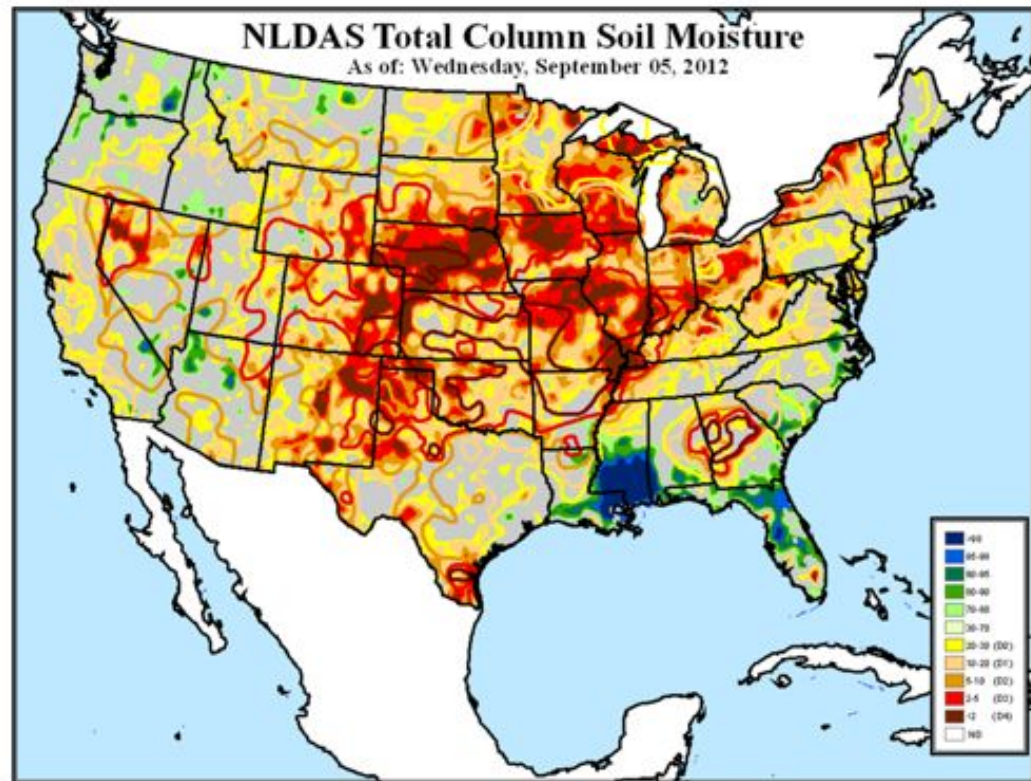
VIC Soil Moisture Percentiles (wrt/ 1916-2004)  
for the period: 20120827 to 20120903



**NLDAS Top 1m Soil Moisture**  
As of: Wednesday, September 05, 2012



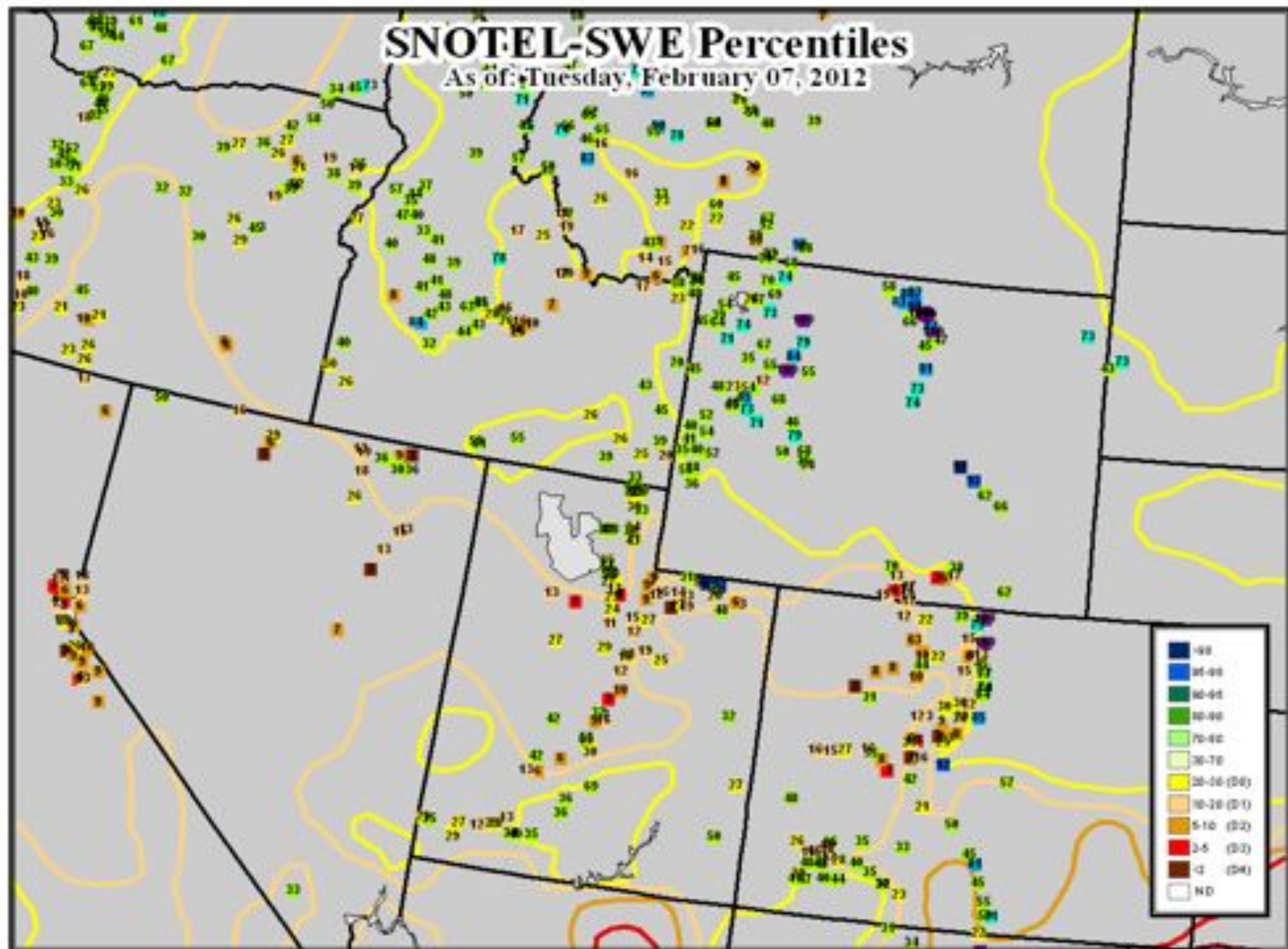
**NLDAS Total Column Soil Moisture**  
As of: Wednesday, September 05, 2012





# SNOTEL-SWE Percentiles

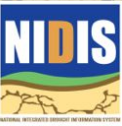
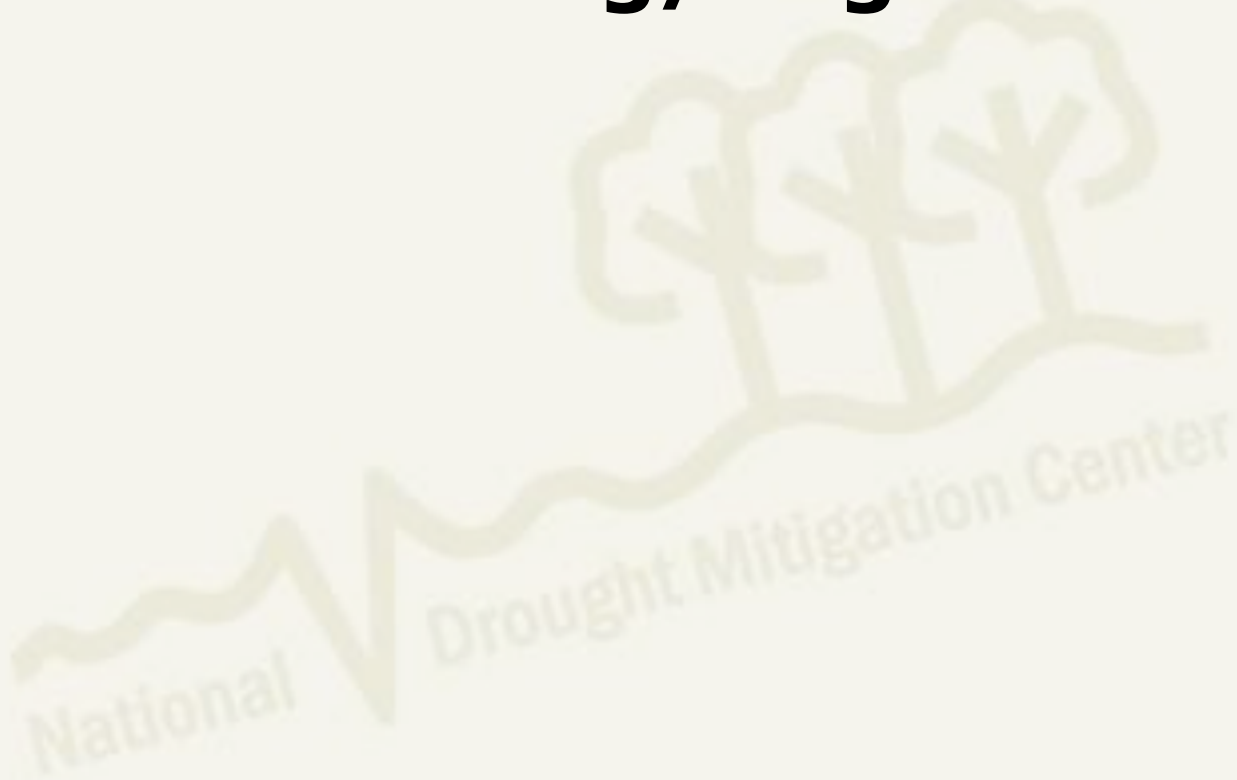
As of: Tuesday, February 07, 2012





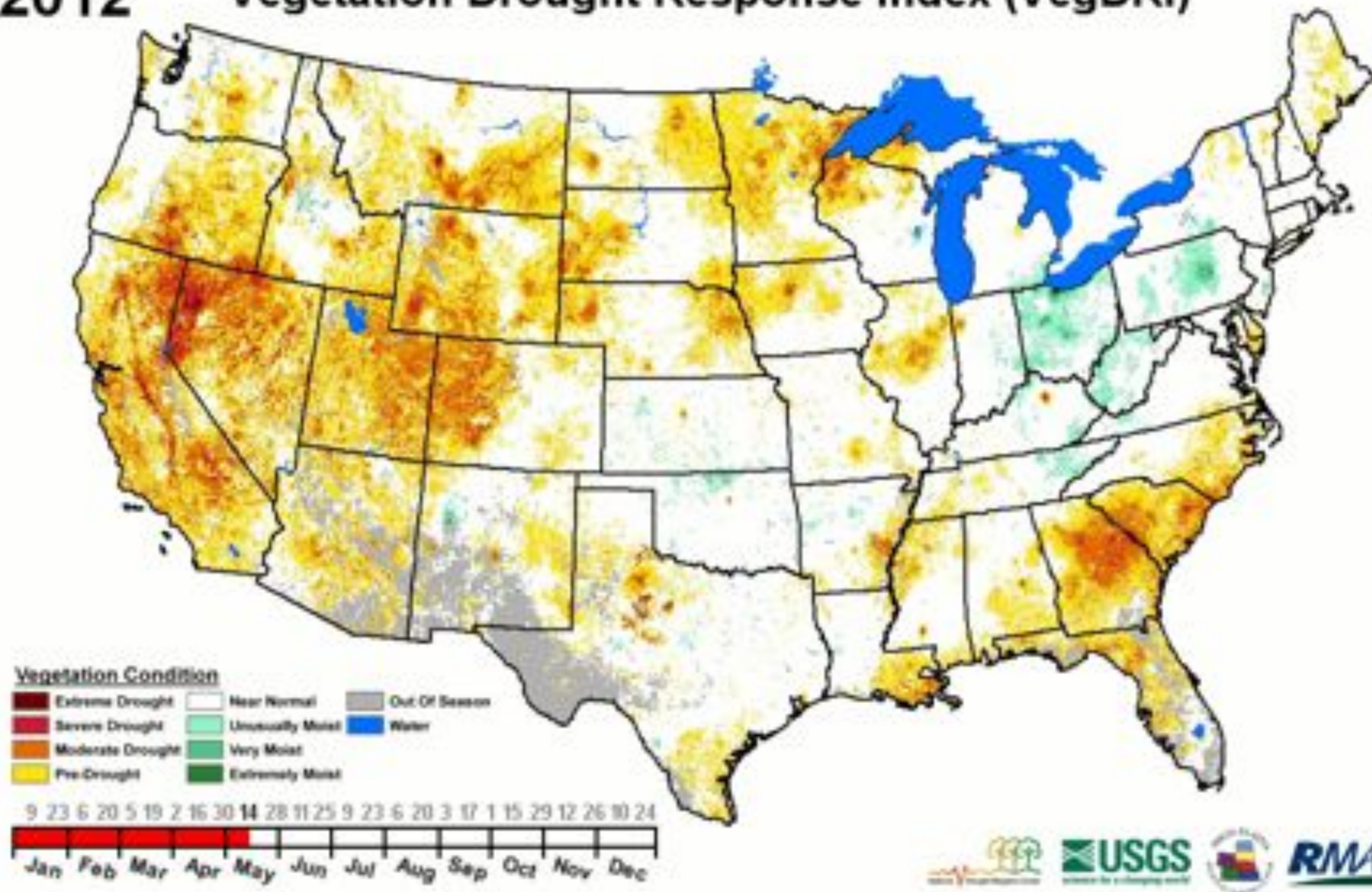


# Remote Sensing/Vegetation Health



2012

# Vegetation Drought Response Index (VegDRI)





# ESI Archive - CONUS



Hydrology & Remote Sensing Lab  
Beltsville, Maryland, USA

Index Timescale

ESI 1 Month

ESI

MSR

USDM

SPI

2012

[Download](#)[Popup](#)

Standardized ET/PET anomalies



Index Timescale

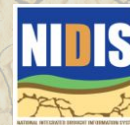
USDM Weekly

Aug 25

2012

[Download](#)[Popup](#)

U.S. Drought Monitor Drought Severity

[View in Pan and Zoom Mode](#)

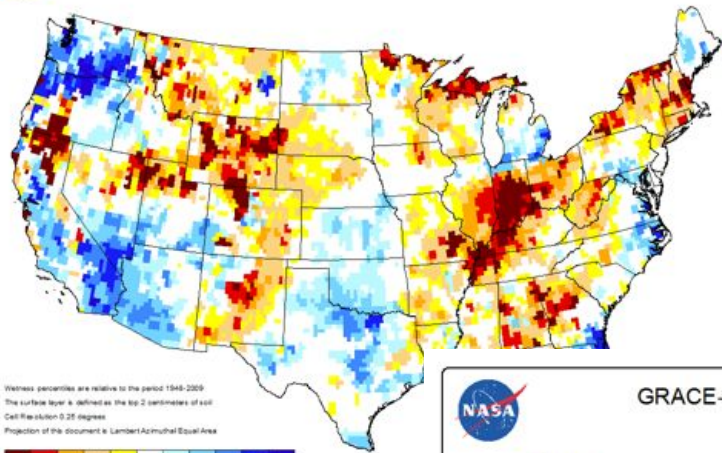
UNIVERSITY OF  
**Nebraska**  
Lincoln





### GRACE-based Surface Soil Moisture

August 27, 2012



Wetness percentiles are relative to the period 1949-2009.  
The surface layer is defined as the top 2 centimeters of soil.  
Cell Resolution: 0.25 degrees.  
Projection of this document is Lambert Azimuthal Equal Area.

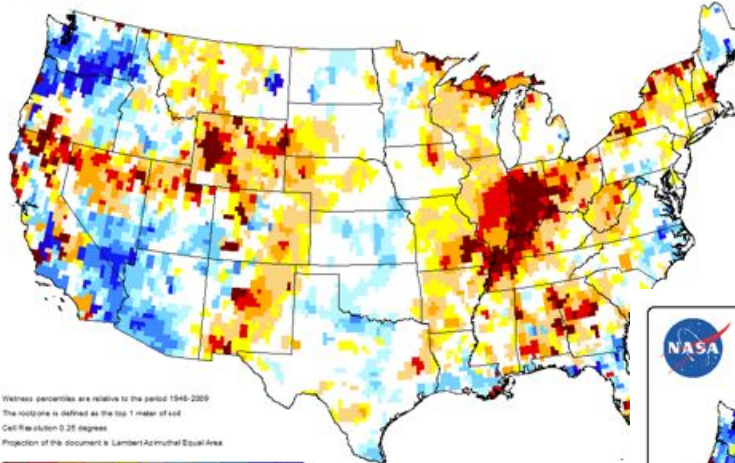


<http://drought.unl.edu>



### GRACE-based Rootzone Soil Moisture

August 27, 2012



Wetness percentiles are relative to the period 1949-2009.  
The rootzone is defined as the top 1 meter of soil.  
Cell Resolution: 0.25 degrees.  
Projection of this document is Lambert Azimuthal Equal Area.

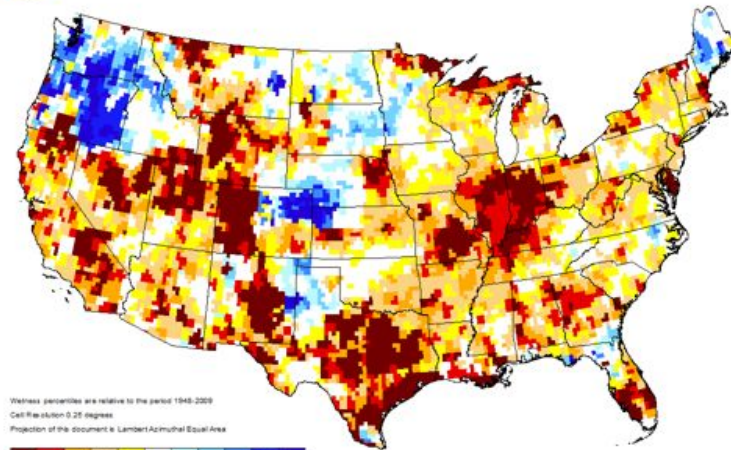


<http://drought.unl.edu/MonitoringTools/NASAGRACEDataAssimilation.aspx>



### GRACE-based Ground Water Storage

August 27, 2012



Wetness percentiles are relative to the period 1949-2009.  
Cell Resolution: 0.25 degrees.  
Projection of this document is Lambert Azimuthal Equal Area.



<http://drought.unl.edu/MonitoringTools/NASAGRACEDataAssimilation.aspx>

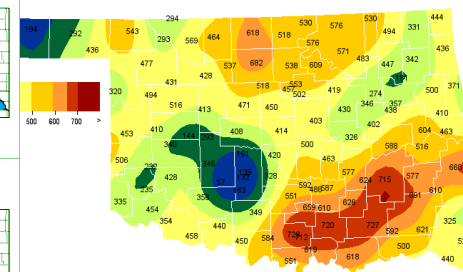
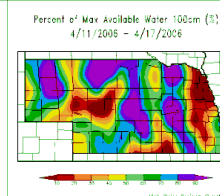
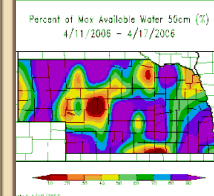
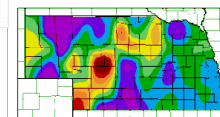
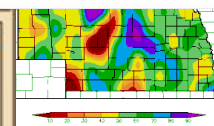
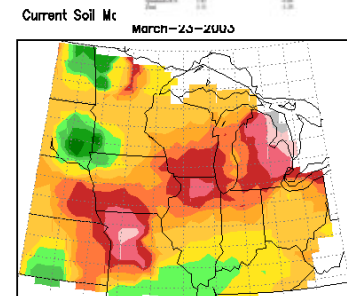
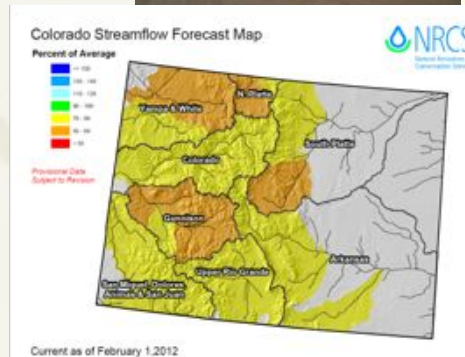
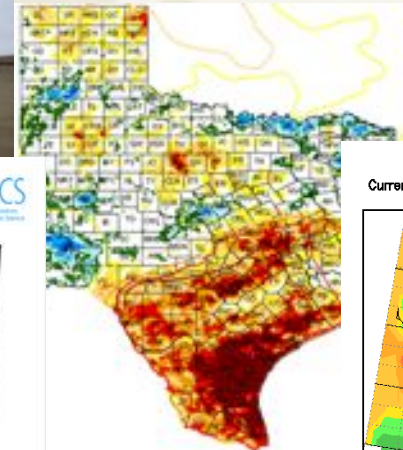


# The Importance of Local Expert Input

## ▶ The U.S. Drought Monitor Team Relies on Field Observation Feedback from the Local Experts for Impacts Information & "Ground Truth"

- **Listserver (~350 Participants: 2/3 Federal, 1/3 State/Univ.)**

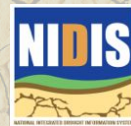
- Local NWS & USDA/NRCS Offices
- State Climate Offices
- State Drought Task Forces
- Regional Climate Centers
- NIDIS Basin Webinars



Copyright (c) 2006 Oklahoma Climatological Survey. All rights reserved.

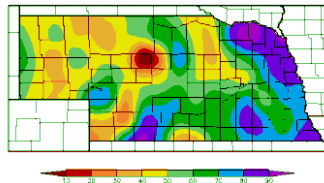
# Regional and Local Products

- Various webinars/telecons/reports
- RCC's
- **SC's**
- NIDIS Pilot DEWS:
  - UCRB
  - ACF
  - CA next?
- NC, HI, TX, AZ, AL, FL

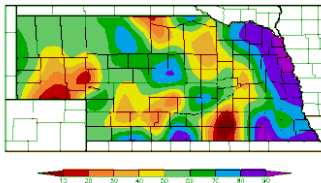




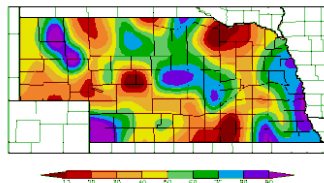
Percent of Max Available Water 10cm (%)  
4/5/2011 - 4/11/2011



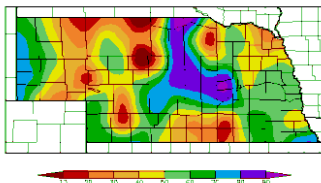
Percent of Max Available Water 25cm (%)  
4/5/2011 - 4/11/2011



Percent of Max Available Water 50cm (%)  
4/5/2011 - 4/11/2011



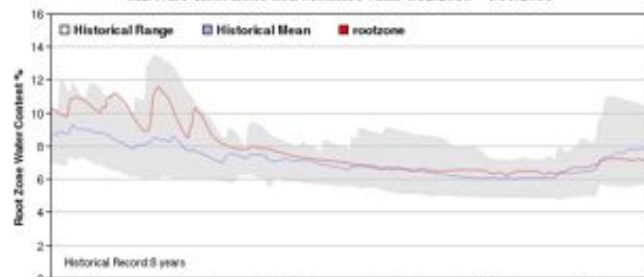
Percent of Max Available Water 100cm (%)  
4/5/2011 - 4/11/2011



Generated 4/12/2011

High Plains Regional Climate Center

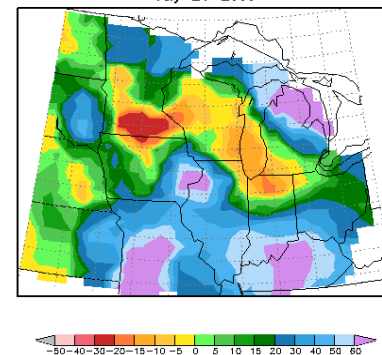
SIDNEY Root Zone Soil Moisture valid 4/12/2010 - 4/11/2011



Elev: 4319.76ft  
Lat: 41.22  
Lon: -103.02

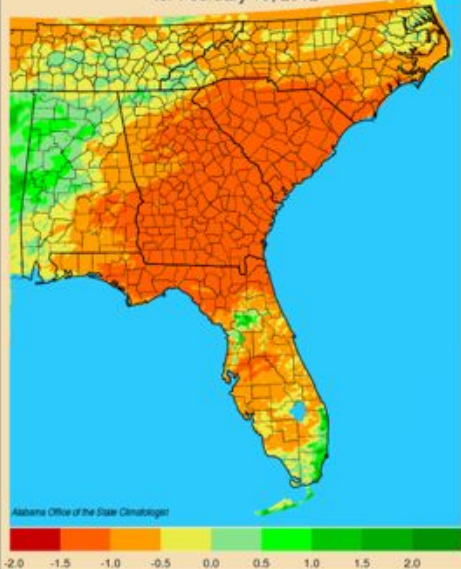
"Experiments" May Contain Preliminary Data  
High Plains Regional Climate Center  
<http://hprcc.unl.edu>

Current Soil Moisture Deviation (σ), depth = 0-12  
July-26-2009



Midwestern Regional Climate Center  
Illinois State Water Survey  
Champaign, Illinois

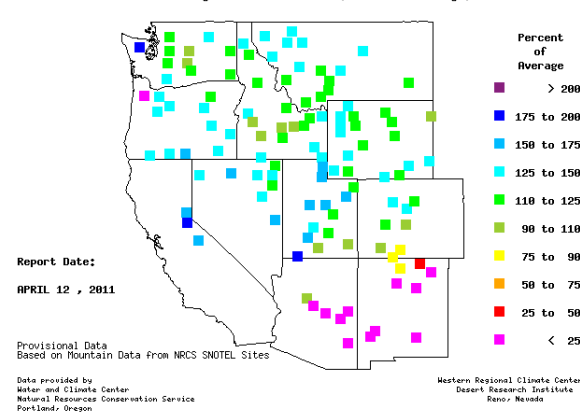
Lawn-and-Garden Moisture Index  
for February 13, 2012



Alabama Office of the State Climatologist

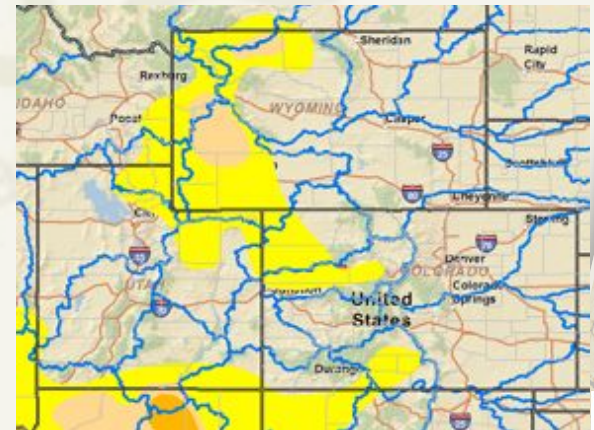
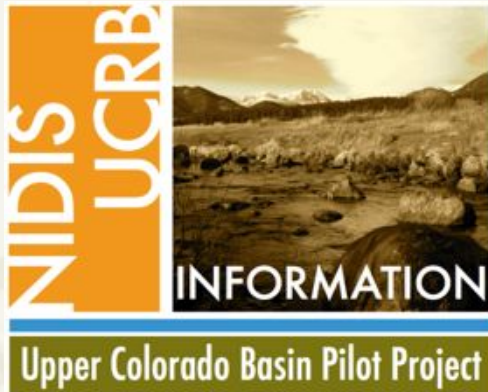
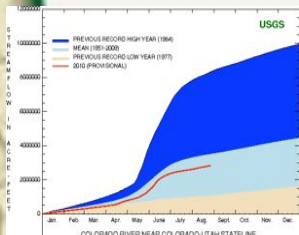
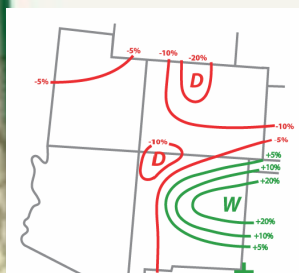
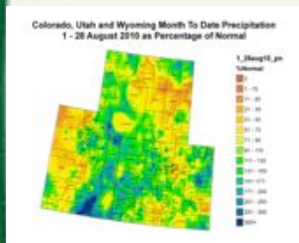
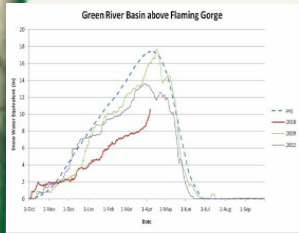
TAMU OSC

Basin Average Snow Water Content. (% of Average.)

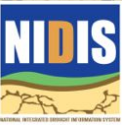


# UCRB Weekly Drought Assessment

<http://www.drought.gov/portal/server.pt/community/ucrb>



**Consensus recommendation  
to USDM author**



UNIVERSITY OF  
**Nebraska**  
Lincoln

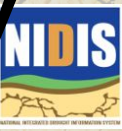




# Some Examples of Decision Making Using the DM

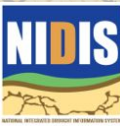
## (Science before Policy)

- ▣ **Policy:** 2008 Farm Bill/Internal Revenue Service/US Department of Agriculture (FAS, NRCS)/NOAA National Weather Service/Environmental Protection Agency/State drought plan triggers
- ▣ **~3.5M+** page views and **~2M+** visitors/year
- ▣ **Media:** The Weather Channel/USA Today and all major newspapers/Internet Media/ Network News/ CNN/NPR/etc.
- ▣ Presidential/Congressional **briefings**



# The U.S. Drought Monitor: Lessons Learned

- ▶ Decision makers/policy makers **want one product with one value**
  - Scientists and resource managers want the details/options
  - Annual feedback Forum's around Canada, Mexico and the U.S.
- ▶ USDM **NOT** based on decision making...**decision making IS based on USDM** though!
- ▶ Transparency
  - Fostered **trust** and became **credible** slowly over time
- ▶ **Communication** (has become U.S. State-of-the-science)
  - Media/public/feedback forums/professional conferences/etc.
  - Agency/State Drought Task Forces
  - Expert list server (local participation and buy-in since Day 1)
- ▶ **Flexible**....continues to adapt and evolve (new tools)
- ▶ **Composite**/hybrid approach (innovative)
- ▶ Has a built in **"historical"** component (ranking percentile approach)
- ▶ **Blend** of Objective (95%)/"Subjective" (5%) works
  - Eyes and ears on the ground
  - Subjective= Local experts provide data, impacts, products to support/refute



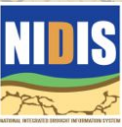


Please visit the NDMC website for more information: <http://drought.unl.edu>



**Thanks!**

Contact me at:  
Mark Svoboda  
402-472-8238  
[msvoboda2@unl.edu](mailto:msvoboda2@unl.edu)



UNIVERSITY OF  
**Nebraska**  
Lincoln



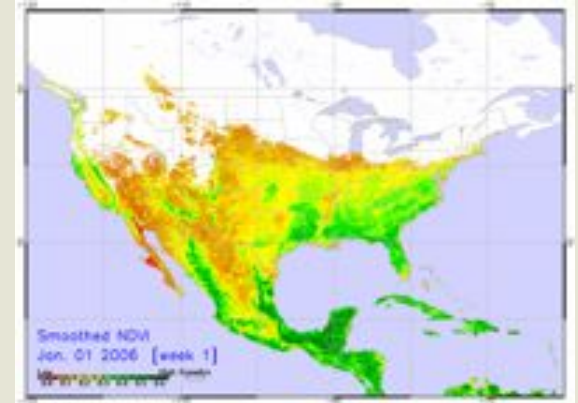
# Satellite Remote Sensing of Drought

## *The Traditional Approach*

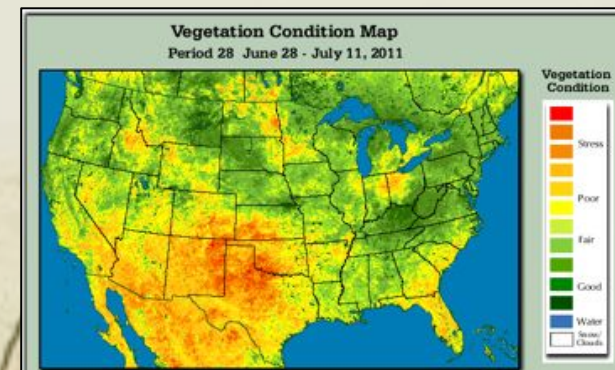
**Normalized Difference Vegetation Index (NDVI)** data from satellite have been used for 20+ years for a wide range of large-area environmental applications including drought monitoring and early warning.

**The NDVI represents an indicator of the general state and condition of vegetation** that is calculated from the mathematical transformation of 2 spectral bands (visible red and near-infrared [NIR]) commonly available of global imagers such as AVHRR and MODIS.

Development of other NDVI-based indices that have been routinely used for drought monitoring including the Vegetation Condition Index (VCI) and Vegetation Health Index (VHI).



Geographic patterns of seasonal vegetation greenness for the U.S. as observed from a time-series NOAA AVHRR NDVI data. (Animation produced by NOAA / NESDIS).





# Inputs into the USDM

## Integrates Key

### Drought Indicators:

- Palmer Drought Index
- SPI
- KBDI
- Modeled Soil Moisture
- 7-Day Avg. Stream flow
- Precipitation Anomalies

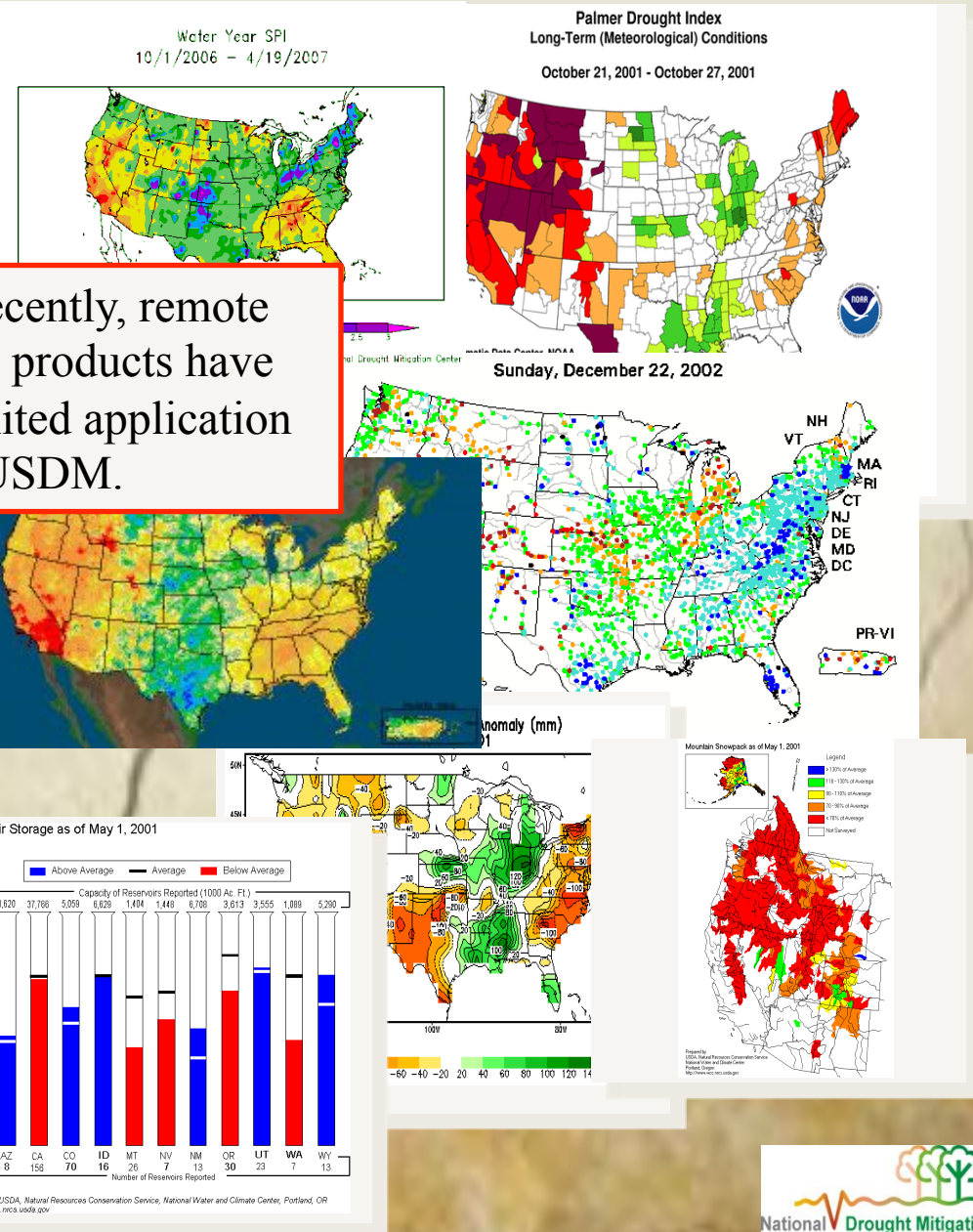
### Growing Season:

- Crop Moisture Index
- **Satellite Veg. Health Index**
- Soil Moisture
- Mesonet data

Until recently, remote sensing products have had limited application in the USDM.

### In The West:

- SWSI
- Reservoir levels
- Snowpack (SNOTEL)
- SWE
- Stream flow

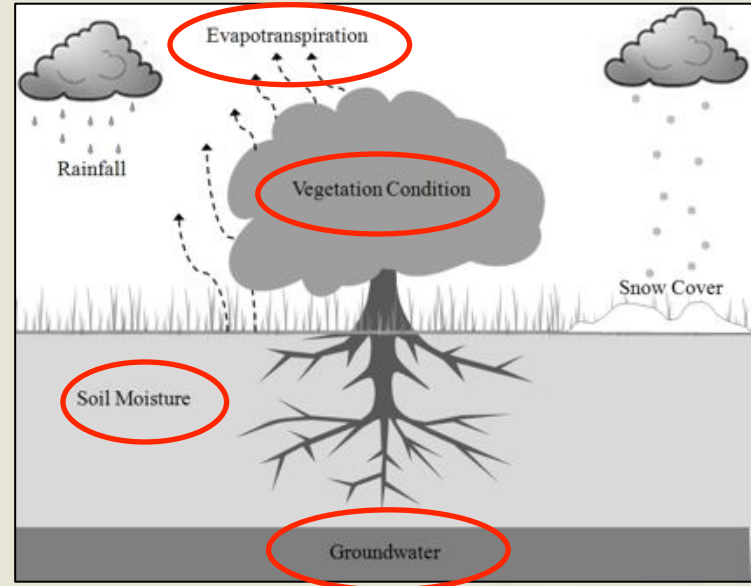


# New Directions in Satellite Remote Sensing of Drought

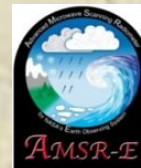
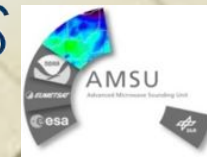
Since the late 1990's, the capability to monitor and map key components of the hydrological cycle have become possible using satellite remote sensing because of:

- 1) the launch of many new sensors collecting a wide array of Earth observations,
- 2) improved computing capabilities, and
- 3) more advanced modeling and analysis techniques.

*Remote Sensing Estimates of:*



*New Remote Sensing Instruments*



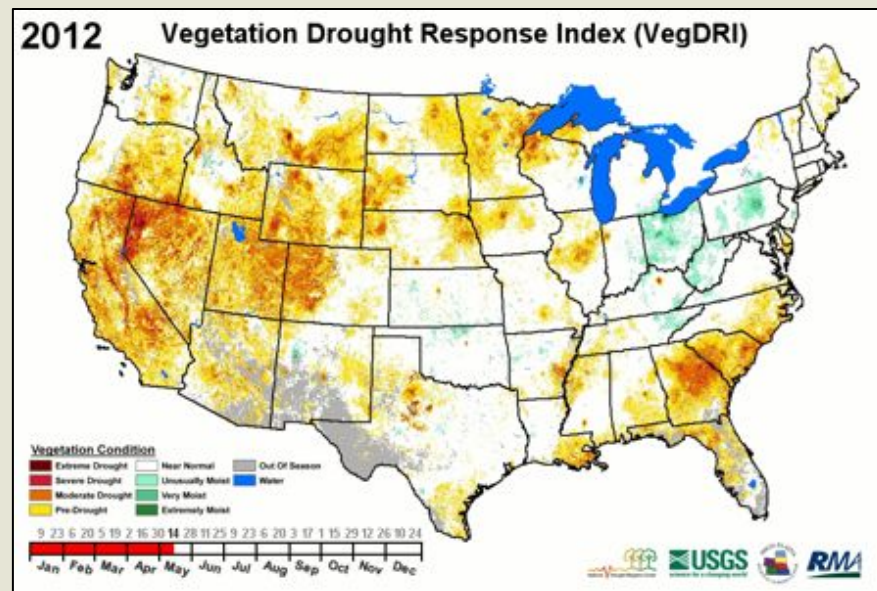


# Vegetation Drought Response Index (VegDRI)

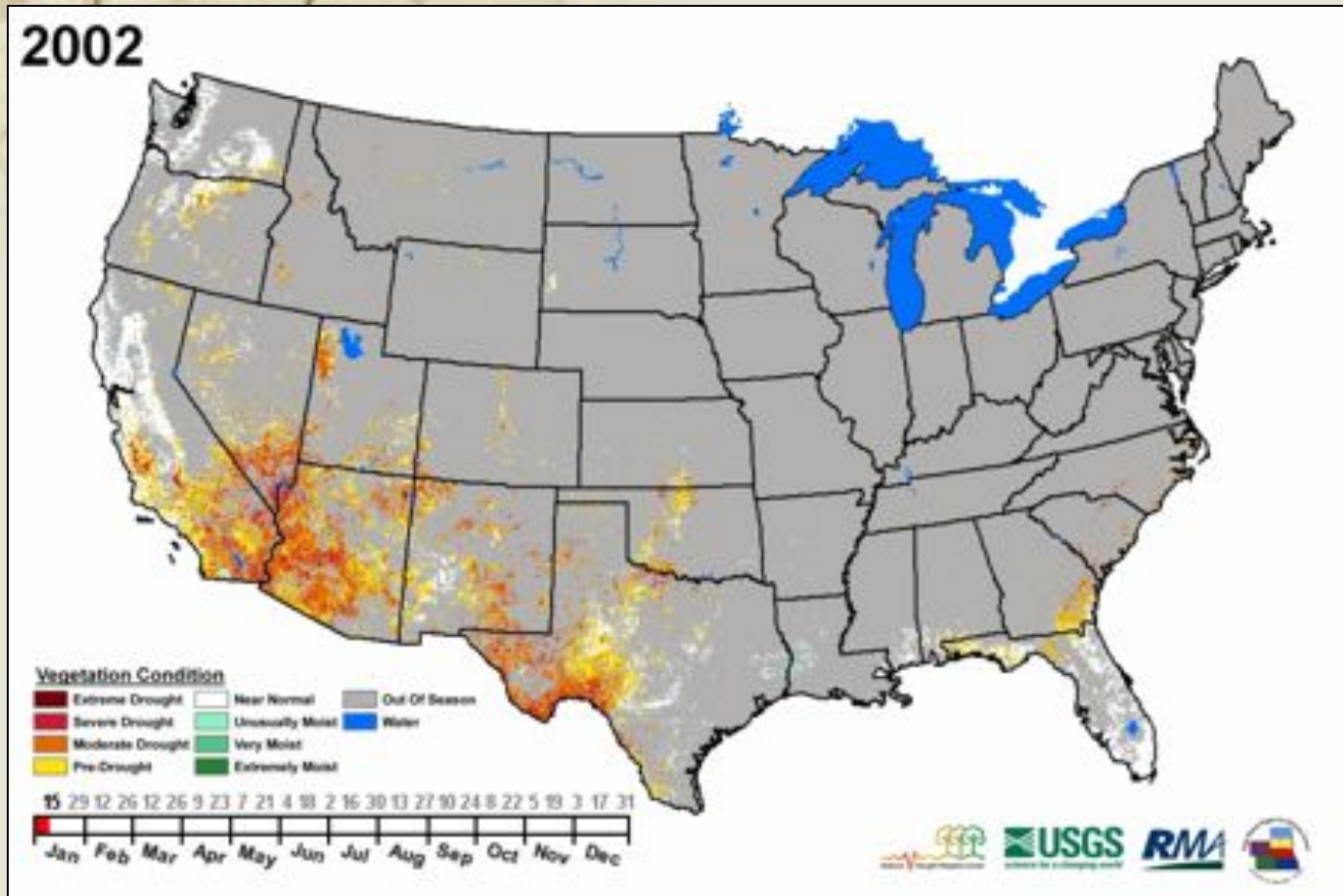
VegDRI is a new 'hybrid' drought index that integrates:

- satellite-based observations of vegetation conditions
- climate-based drought index data
- biophysical characteristics of the environment

to depict '*drought-related*' vegetation stress.



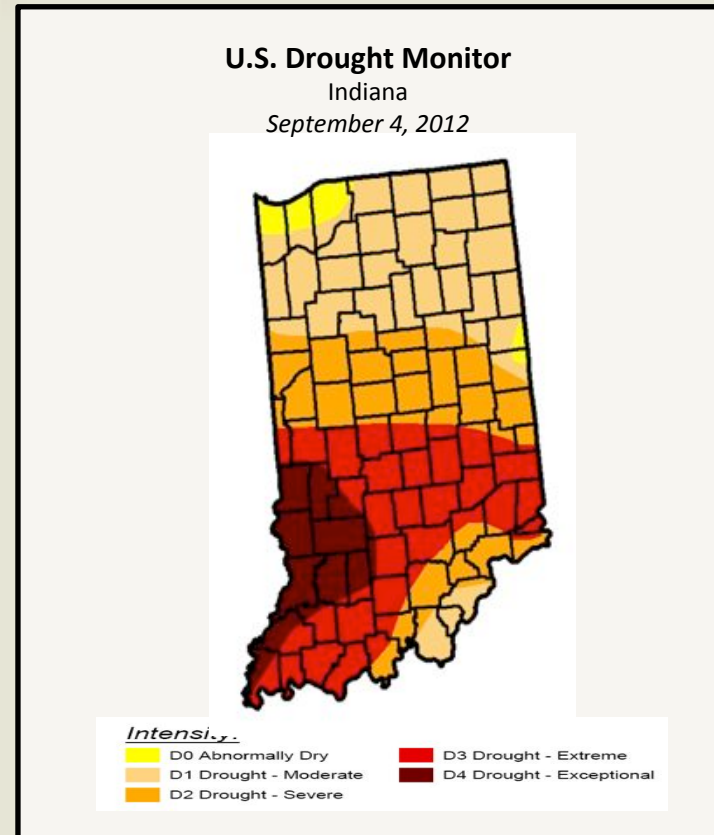
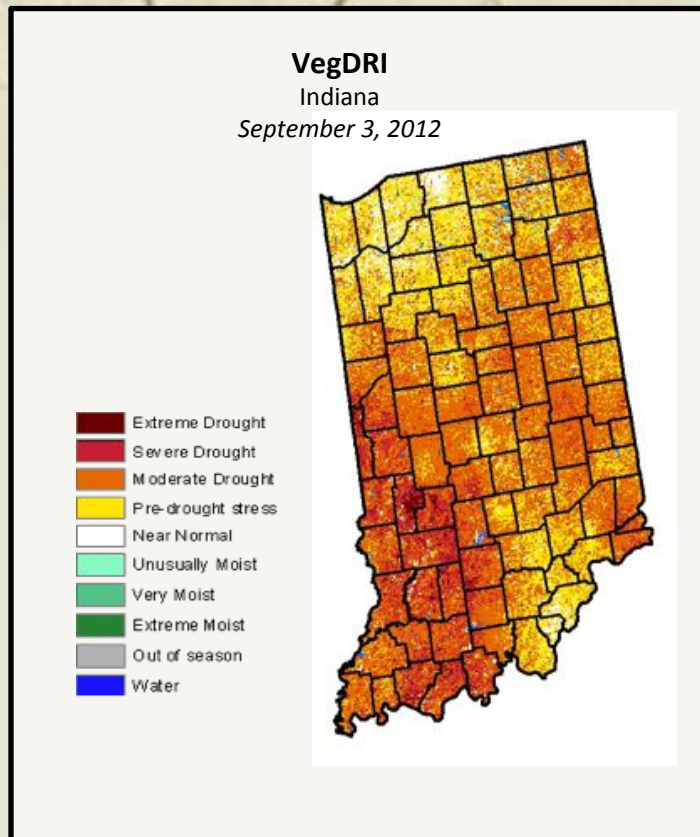
# Goals of VegDRI



1. Implement a **drought severity classification scheme** that was **easily interpretable** (modified Palmer Drought Severity Index [PDSI] classification scheme).

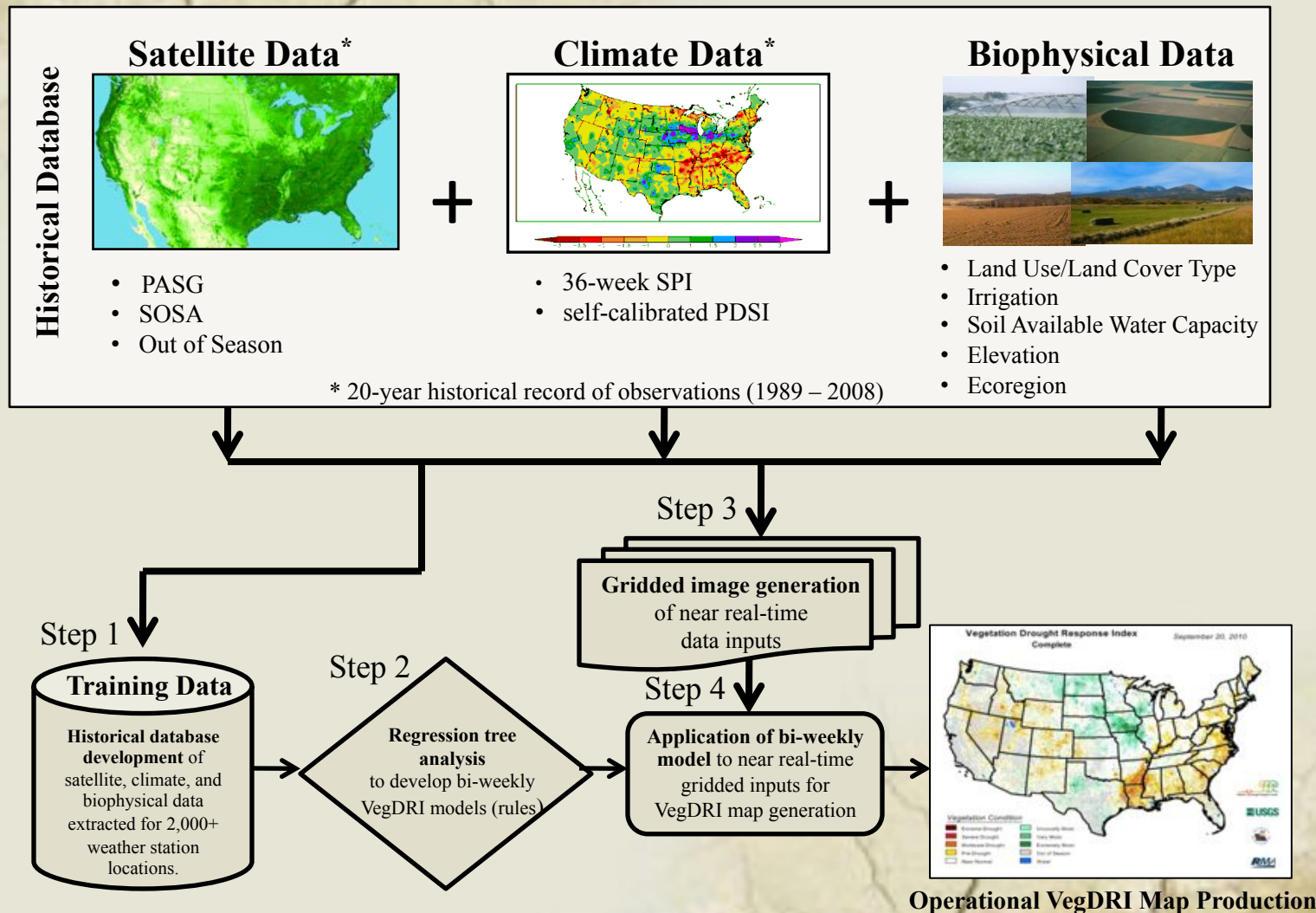


# Goals of VegDRI



2. Develop a tool with **national-level monitoring** capabilities that provides **local-scale information** (i.e., county to sub-county level) regarding the level of drought stress on vegetation.

# VegDRI Methodology

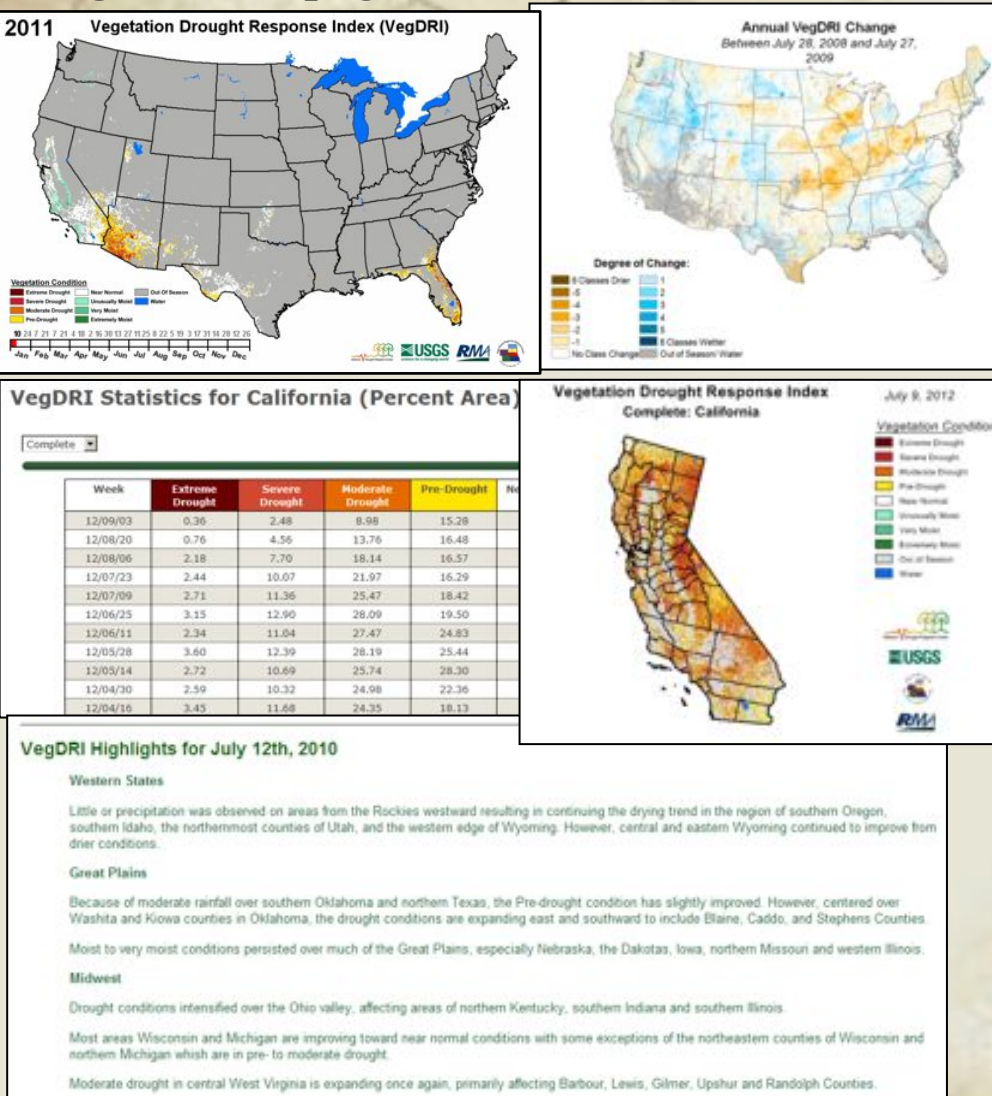


Brown, J.F., **B.D. Wardlaw**, T. Tadesse, M.J. Hayes, and B.C. Reed. 2008. The vegetation drought response index (VegDRI): a new integrated approach for monitoring drought stress in vegetation. *GIScience and Remote Sensing* 45(1):16-46.



# Operational VegDRI Products

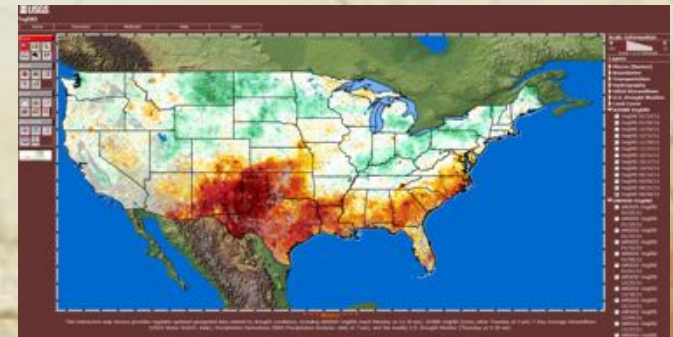
**VegDRI Webpage** <http://vegdiri.unl.edu/>



- Weekly (MODIS) & bi-weekly (AVHRR) production over the continental U.S.
- 20+ year time series of maps dating back to 1989
- Standard value-added products
  - National, state, and sub-state maps
  - Change maps
  - Area statistics
  - Descriptive map narrative
  - Animations

## USGS Interactive VegDRI Map Viewer

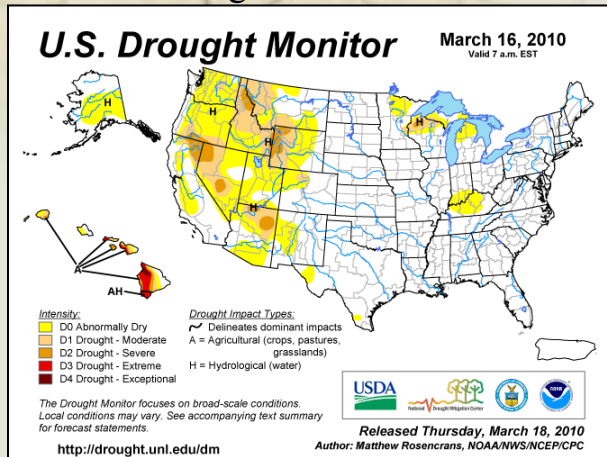
<http://vegdiri.cr.usgs.gov/viewer/viewer.htm>



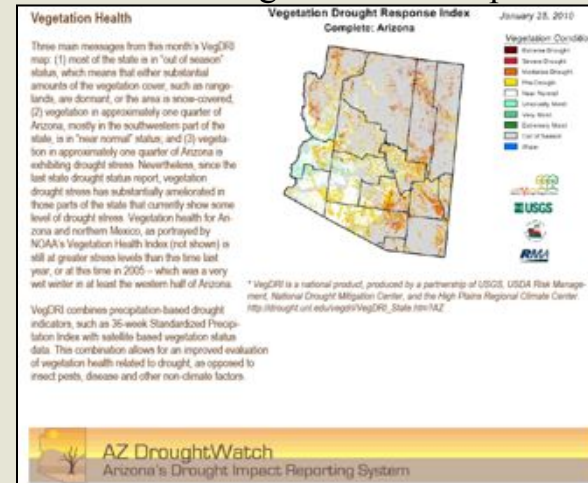
# Who is Using VegDRI?

## Examples...

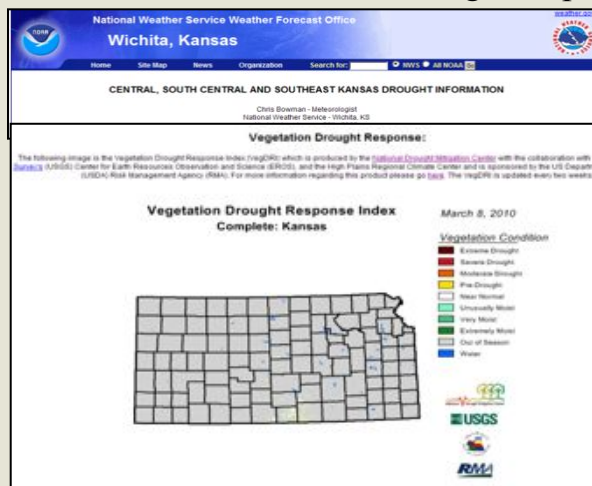
### U.S. Drought Monitor authors



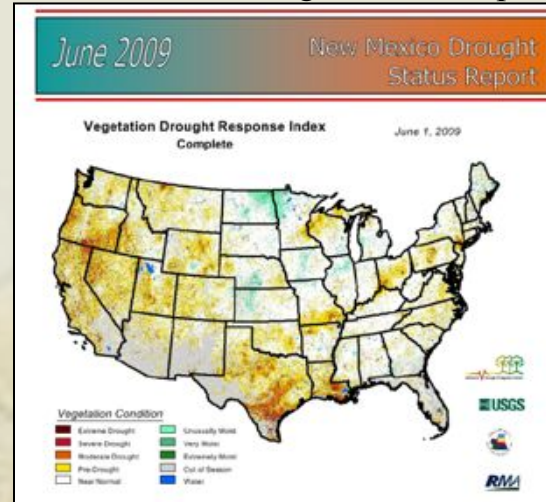
### Arizona Drought Monitor Report



### National Weather Service Drought Reports



### New Mexico Drought Status Report



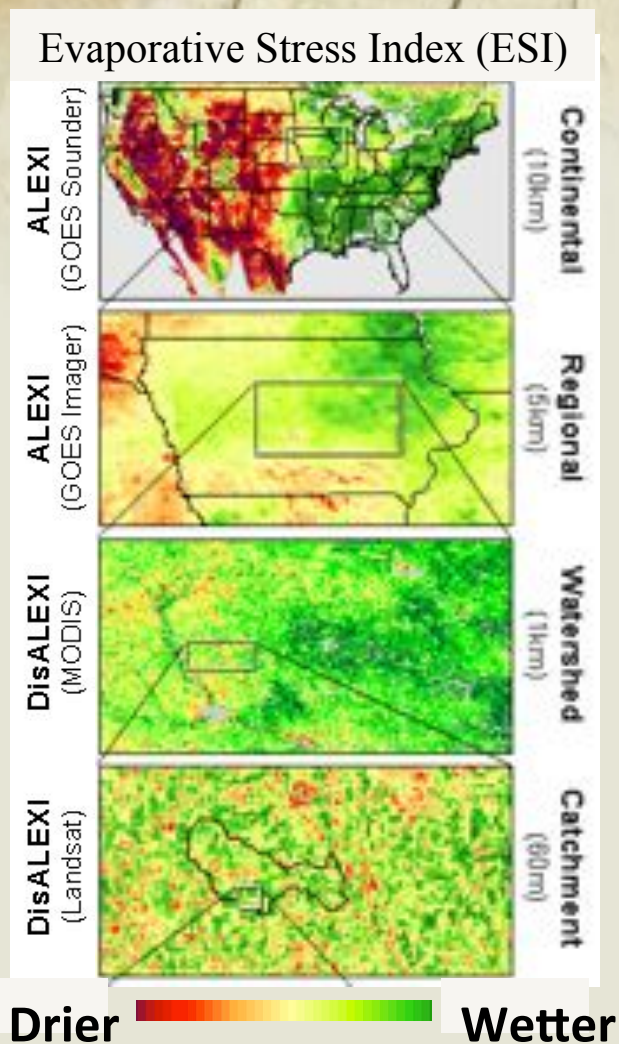


# International VegDRI Efforts

- Canada\* – seamless U.S.-Canada coverage for North American Drought Monitor
- Czech Republic\* – for Central Europe
- Mexico\*
- Ethiopia and Great Horn of Africa
- India
- Argentina

\* Efforts currently under way.

# Evaporative Stress Index (ESI)



ESI depicts ‘transpiration’ fluxes from vegetation and ‘evaporative’ fluxes from non-vegetated surfaces (e.g., soils) using thermal observations from satellite in a surface energy balance model.

ESI can be derived separately for the *vegetation canopy* ( $ESI_v$ ) and *soil surface* ( $ESI_s$ ) using the a two-source modeling method.

ESI can be calculated from data from many instruments to provide range of *calculations across multiple spatial and temporal scales*

Minutes to Hourly: GOES- & Meteosat-derived 5- to 10-km ESI maps

Daily to weekly: MODIS-derived 1-km ESI maps

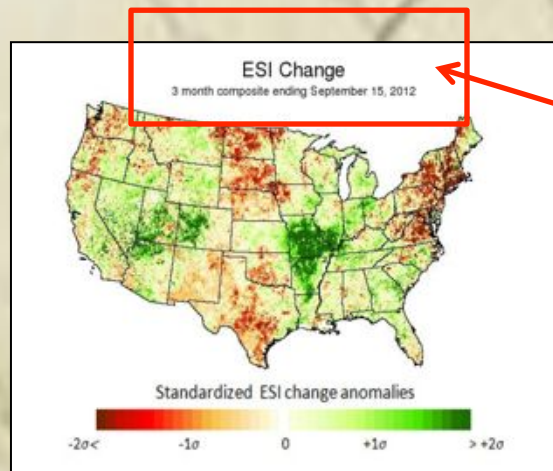
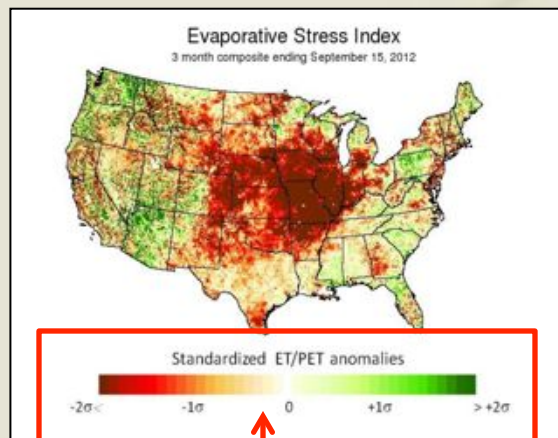
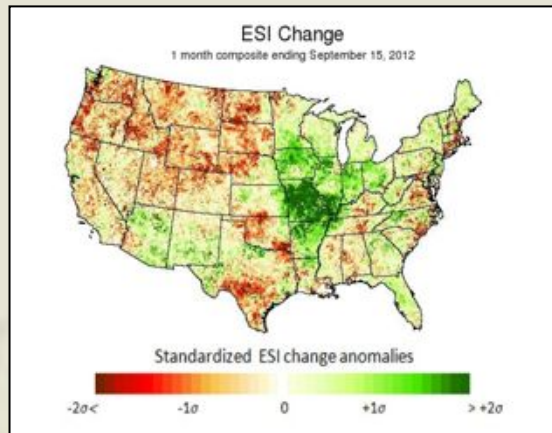
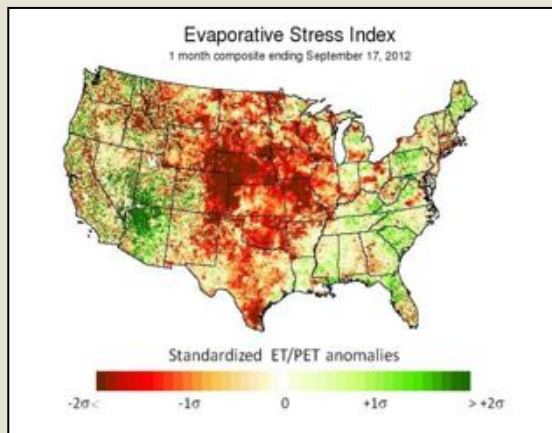
Bi-weekly (16-days): Landsat 60- and 120-m ESI maps

Anderson, M.C., C. Hain, B. Wardlow, A. Pimstein, J.R. Mecikalski, and W.P. Kustas. 2011. Evaluation of a drought index based on thermal remote sensing of evapotranspiration over the continental U.S. *Journal of Climate* 24:2025-2044.





# Suite of ESI Anomaly Products

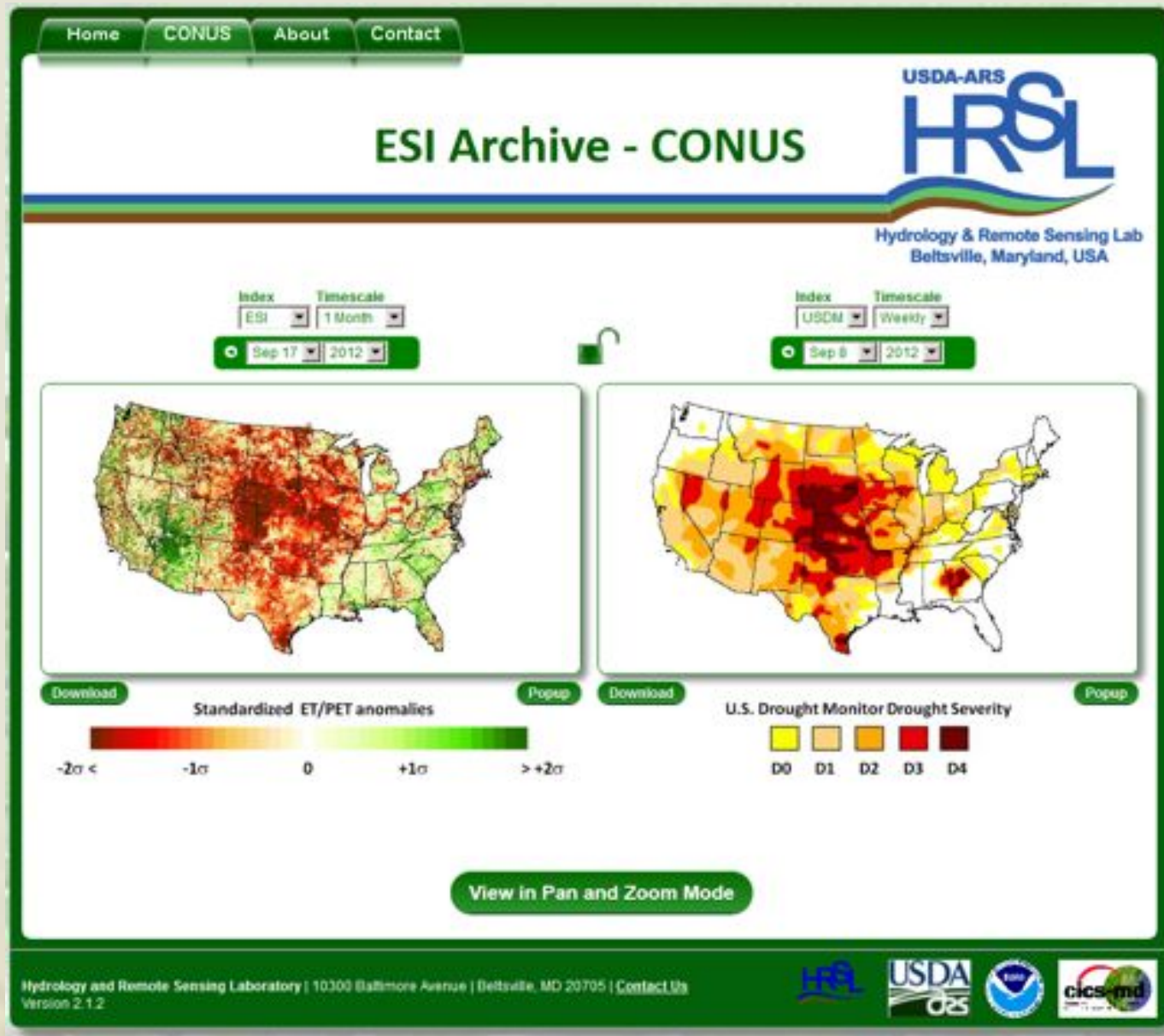


- Weekly, 10-km maps over continental U.S.
- Initial integration into the USDm in 2011
- 12-year historical record of ET-related anomaly products (2000 to present)

Change products over different time intervals (1, 2, and 3 months) to capture shorter and longer-term changes in conditions.

Color scheme compatible with USDm.





<http://hrsl.arsusda.gov/drought/index.php>

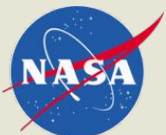
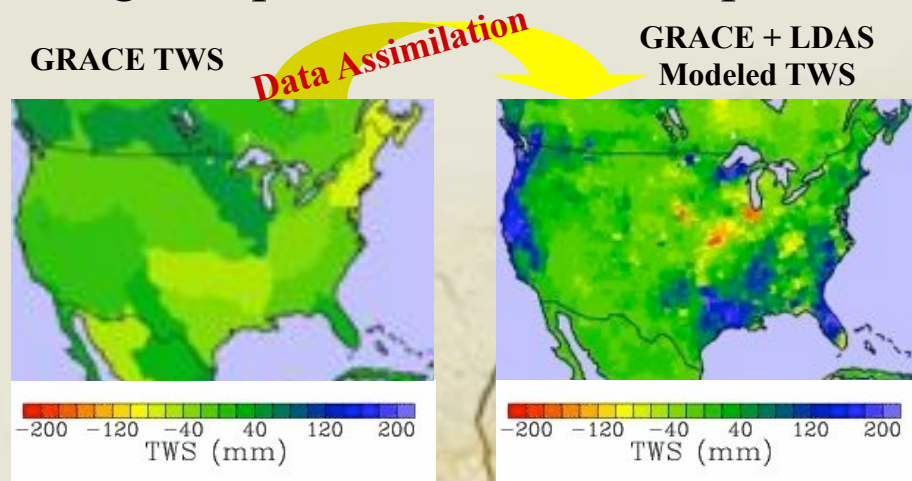


# GRACE Terrestrial Water Storage (TWS)

Terrestrial Water Storage (TWS) is the vertical summation of :

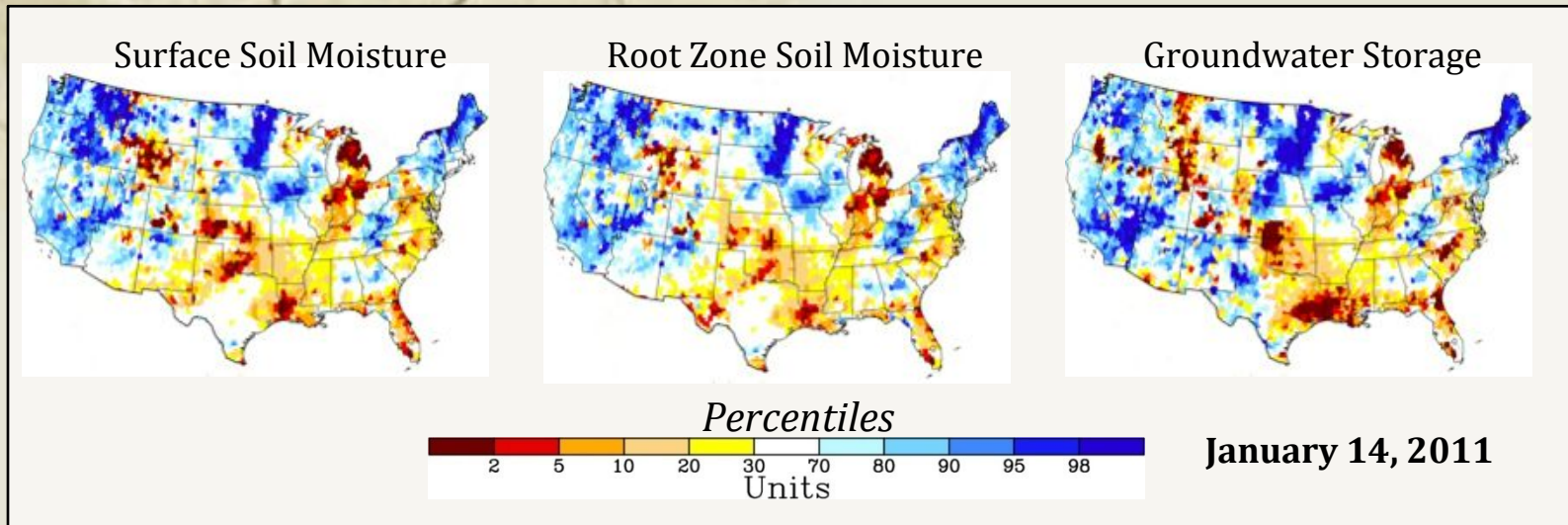
- 1) surface water
  - 2) snow
  - 3) soil moisture
  - 4) groundwater
- ✓ Gravity data acquired by the GRACE (Gravity Recovery and Climate Experiment) instrument is processed through Land Data Assimilation System (LDAS) to estimate water storage for each vertical layer and downscale information to higher spatial resolution output.

Zaitchik, B.F., M. Rodell, and R.H. Reichle,  
2008: Assimilation of GRACE Terrestrial Water  
Storage Data into a Land Surface Model: Results  
for the Mississippi River Basin. *J. Hydrometeor.*,  
9, 535–548.



Courtesy: Matt Rodell, NASA GSFC

# GRACE TWS Products



<http://drought.unl.edu/MonitoringTools/NASAGRACEDataAssimilation.aspx>

- Weekly TWS products are produced at a nominal spatial resolution of ~4 degrees for moisture conditions at different depths of the Earth's surface and sub-surface including:
  - surface soil moisture
  - root zone soil moisture
  - groundwater





# Soil Moisture Change (SMC)

- ✓ Soil moisture changes (SMC) estimated using backscatter data acquired from NASA's QuikSCAT and AMSR-E instruments.



QSCAT Soil Moisture Change (upper 5 cm)

- ✓ Experimental SMC products for the continental U.S.

## *SMC Product Characteristics:*

- Nominal spatial resolution of 25-km
- Weekly updates of maps

- ✓ PI: Son Nghiem (JPL)

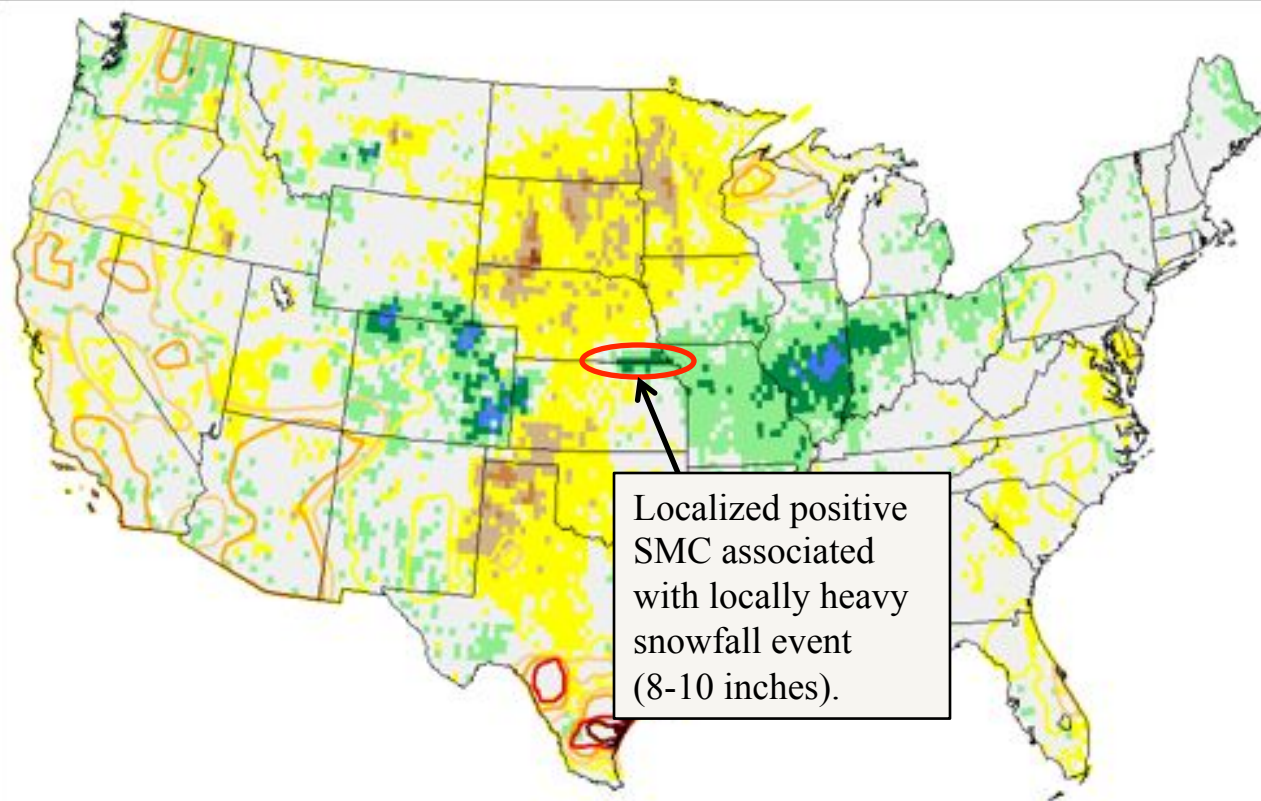


# Soil Moisture Change, 7 Day Average, 2009-Nov-16 to Nov-22 & 2009-Nov-17 Drought Monitor

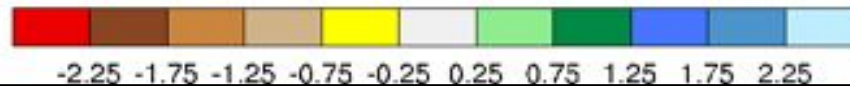
Experimental Product by NASA/JPL; CalTech; NOAA/ESRL/PSD; CU/CIRES/CDC

From QuikSCAT satellite active radar

dB backscatter difference

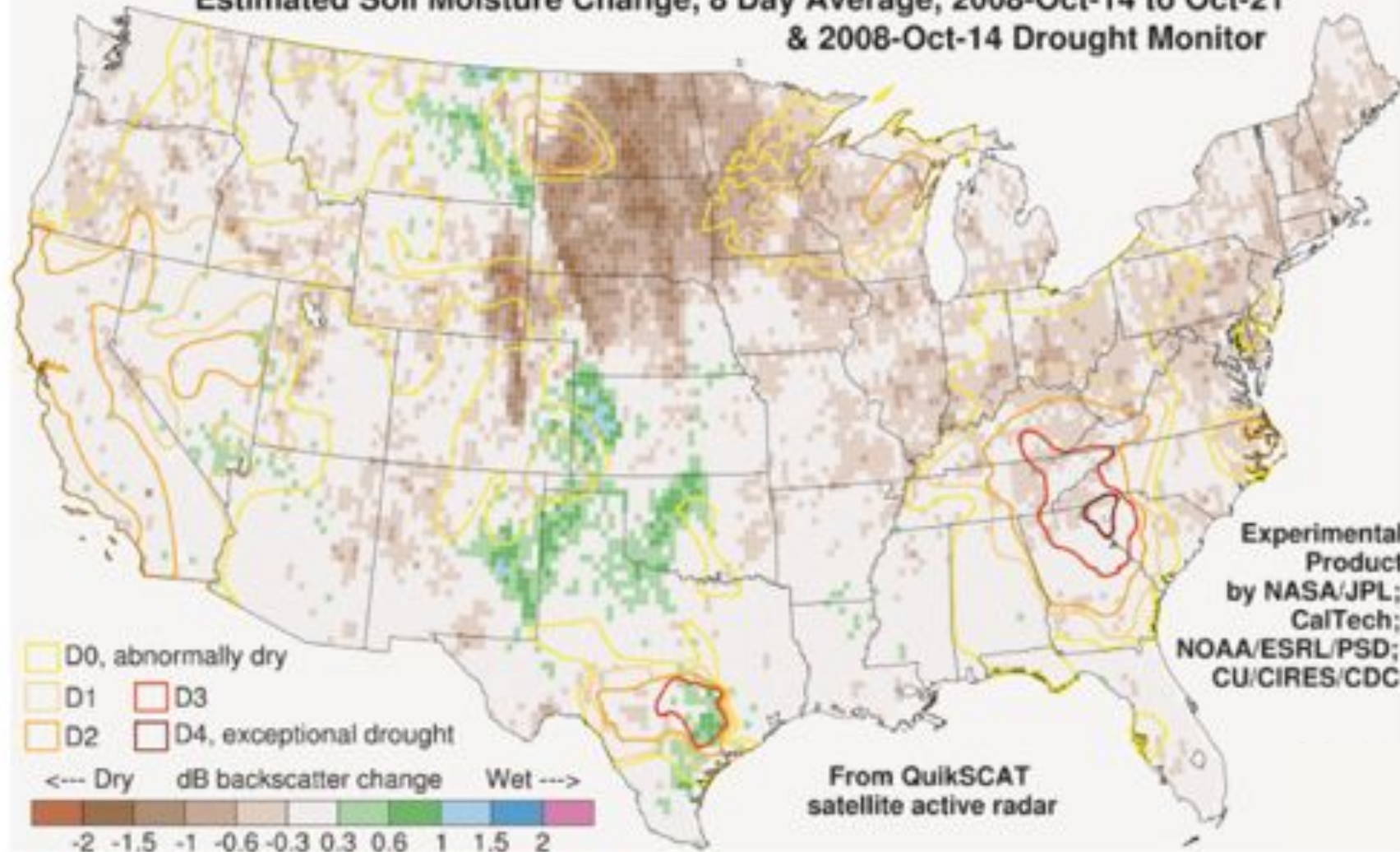


Localized positive  
SMC associated  
with locally heavy  
snowfall event  
(8-10 inches).



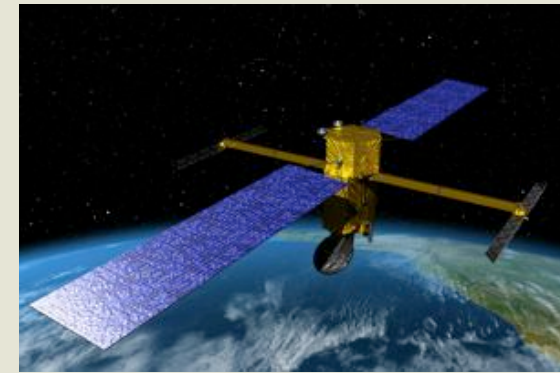
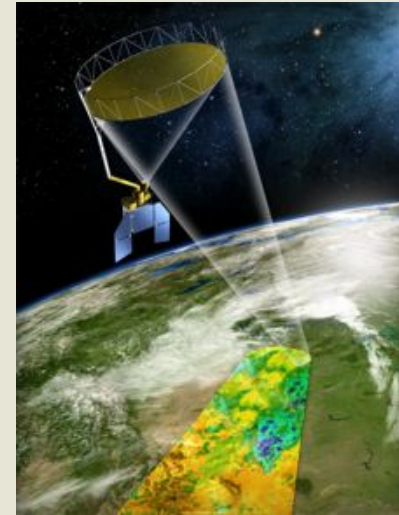


**Estimated Soil Moisture Change, 8 Day Average, 2008-Oct-14 to Oct-21  
& 2008-Oct-14 Drought Monitor**



# Future Prospects

- **Soil Moisture Active Passive (SMAP)**
  - high spatial resolution soil moisture information
  - soil moisture representative of greater depths (i.e., root zone)
- **Surface Water Ocean Topography (SWOT)**
  - support hydrologic drought monitoring
  - water level variations in inland water bodies
- **Visible/Infrared Imaging Radiometer Suite (VIIRS) on NPOESS**
  - continuity data for vegetation index data records developed from AVHRR and MODIS





# Final Thoughts

- **Benefit of early engagement of decision makers in remote sensing tool and product development** - more rapid adoption of information into drought monitoring activities
- **Customization of tools and products for drought has fostered a broader group of decision makers using the information.**
- **Continued validation of remote sensing products within a ‘drought’ context is still needed.** Early feedback is positive, but more thorough and sustained quantitative validation required.
- **Operational product support and the availability of long-remote sensing observations, particularly for research instruments, is an issue.** *Key concern:* Will these operational drought products and the necessary remote sensing data inputs be available in the future?

**Thank you for your attention!**

For further information about the USDM or the drought-related remote sensing projects,  
please contact:

**Mark Svoboda**  
**msvoboda2@unl.edu**

**or**

**Brian Wardlow**  
**bwardlow2@unl.edu**